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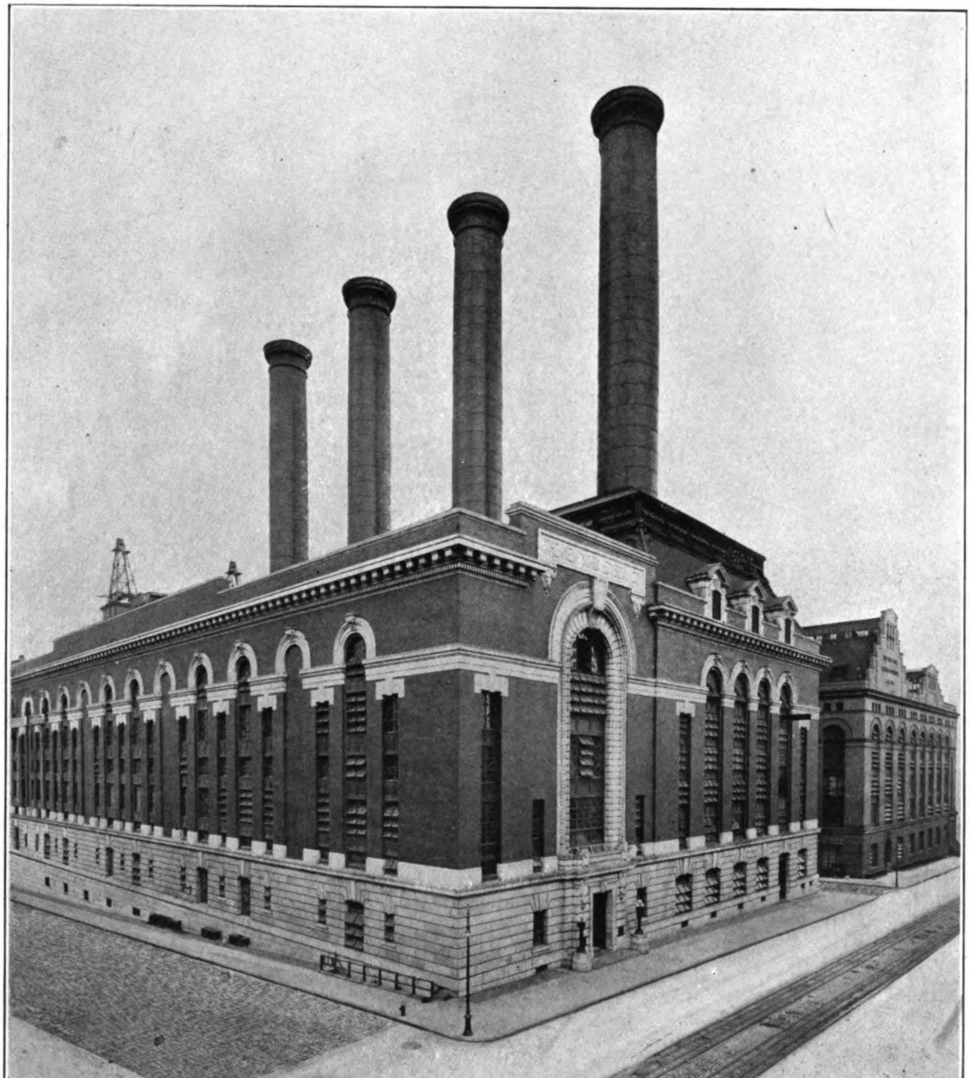

Waterside Power Stations—The New York Edison Company.

ELECTRIC POWER PLANTS

A DESCRIPTION OF A NUMBER OF POWER STATIONS

DESIGNED BY

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INTRODUCTION

The object of the present work is to exhibit the engineering details of certain modern electric lighting and power plants which represent the most advanced design and construction. They comprise the largest stations of the New York Edison Company in the Borough of Manhattan, the new power stations of the Brooklyn Rapid Transit Company, the Gold Street station of the Kings County Electric Light and Power Company, two stations in smaller cities (Rochester and Utica, N. Y.), one industrial power plant and one hydro-electric plant. The two Waterside stations of the New York Edison Company not only exhibit the installation and operation of units of exceptional size and large output, but of the many expedients required to ensure continuous service throughout a great city area, and the consequent meeting of every conceivable emergency. The central power station of the Brooklyn Rapid Transit Company represents a system of high-tension distribution with rotary converter substations, and is a radical departure from the earlier system of operating trolley systems by primary generation or direct current with reliance upon boosters for long distances. The single large station delivers current to any part of the system without excessive loss, and underground high-tension feeders replace heavy overhead cables. The result is great flexibility and ample provision for future growth wherever this may become necessary. The Williamsburg power station is a high-tension station, especially showing the application of horizontal steam turbines as prime movers. The Gold Street station of the Kings County Electric Light and Power Company, operated by the Edison Electric Illuminating Company of Brooklyn, is an example of the earlier engine-driven station rebuilt as a turbine-driven station. The central station of the Citizens' Light & Power Company of Rochester, New York and the Washington Street power station of the Utica Gas & Electric Company are typical installations for light and power in small cities, and the power plant of the Helderberg Cement Company illustrates an industrial plant wherein exceptional local conditions had to be met. The station of the Chattanooga and Tennessee River Power Company is representative of recent application of water power to the production of electric energy.

With the aim of making the book of practical utility to the electrical engineer and power station builder, the author, who was also the designer of the plants and supervised their construction, has confined himself to the exposition of facts and of data valuable for purposes of comparison; and chiefly so as a guide, or collection of precedents likely to be of service to others having similar problems to solve, and, therefore, he has omitted all theoretical discussions.

The author takes pleasure in acknowledging the efficient co-operation he has received in the preparation of the original plans and in the compilation of these pages from the technical staffs of The New York Edison Company and of the other corporations whose plants are described.

The extensions and improvements in the properties referred to herein have been made possible on the financial side by the constructive genius of Anthony N. Brady, Esq., and his intelligent appreciation of the importance of the highest obtainable plant efficiency from the operating as well as the investment standpoint.

THOMAS E. MURRAY.

January, 1910.

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WATERSIDE STATION No. 1

ELECTRIC POWER PLANTS

WATERSIDE STATION NO. 1.

GENERAL.

The general rule for the location of a central station, that it shall be located, as nearly as possible, at the center of gravity of the system, is often modified by the cost of land, availability of water supply, coaling facilities and various local considerations. The Waterside station of the New York Edison Company is admirably situated to satisfy all these requirements.

Modern central station work involves the operation of electrical and mechanical units of exceptional size, turning out immense quantities of power. Furthermore, the load on these units is governed by a wide and incessant fluctuation of demand. To maintain service, with no interruptions or shut-downs, under these conditions, is the vital problem. The New York Edison Company has made an enviable record for continuous service, but to assure this result, the company has made provision for almost every possible emergency. In order to accomplish this safe-guarding, many novel means have been employed and great expense incurred.

The main feature of the design of the Waterside No. 1 station is the provision for handling emergencies without interruption of service. The aim was to provide for any blowout, short-circuit or other accident in such a manner that the rest of the system, not directly affected, should not be tied up. In accomplishing this result, the basic idea has been that of isolating and insulating all feeders, connections, leads, buses, etc., so thoroughly that any trouble on one line cannot possibly communicate to any other line.

Furthermore, while each generating system may thus be efficiently separated from the others, it can be tied in with any other unit at will. The same idea has been carried out in the cable and subway system, each substation receiving its current from the power house by at least two separate cables following entirely different routes, resulting in a complete duplication of the transmission system. The result is the most flexible and at the same time homogeneous generating system yet devised.

Waterside Station No. 1 is located on First Avenue, covering the block between Thirty-eighth and Thirty-ninth Streets, and running to the East River, an area of 272½ ft. by 197½ ft. The bulkhead line is 160 ft. distant from the east end of the station, and separated from it by a new marginal street 125 ft. wide, under which pass the condensing tunnels and ash conveyors. The foundations for both engines and building are of concrete and rest directly upon bed rock, affording an exceptionally solid construction.

GENERAL LAYOUT.

The operating room, which occupies the southern half of the building, with its longest dimension parallel to Thirty-eighth Street, contains 11 reciprocating engine-generating units and five vertical turbo-generators, arranged in two rows on opposite sides of a longitudinal aisle. On the west and south sides of the building are the electrical galleries and mezzanines. The exciter sets and motor generators for supplying the station light and power are on the main floor under the galleries. The west end of the operating room is occupied by the switchboards. Below the operating floor are located the condensers, pumps and various auxiliaries and piping.

In the boiler house, which constitutes the northern half of the station, there are two floors of boilers, 28 boilers to a floor, 14 on each side of the longitudinal firing aisle. In the boiler house basement are the ash car tracks, secondary heaters and the blowers for the first tier forced draft system. The blowers for the second tier are set just under the second tier floor, the ducts running in front of the boilers, under the floor.

The coal bunkers occupy the top of the boiler house, surmounted by a glass monitor in which operates the coal conveyors from the coal tower. The latter, which also contains the ash pocket and ash-handling machinery, is set on the bulkhead on the river side of the station.

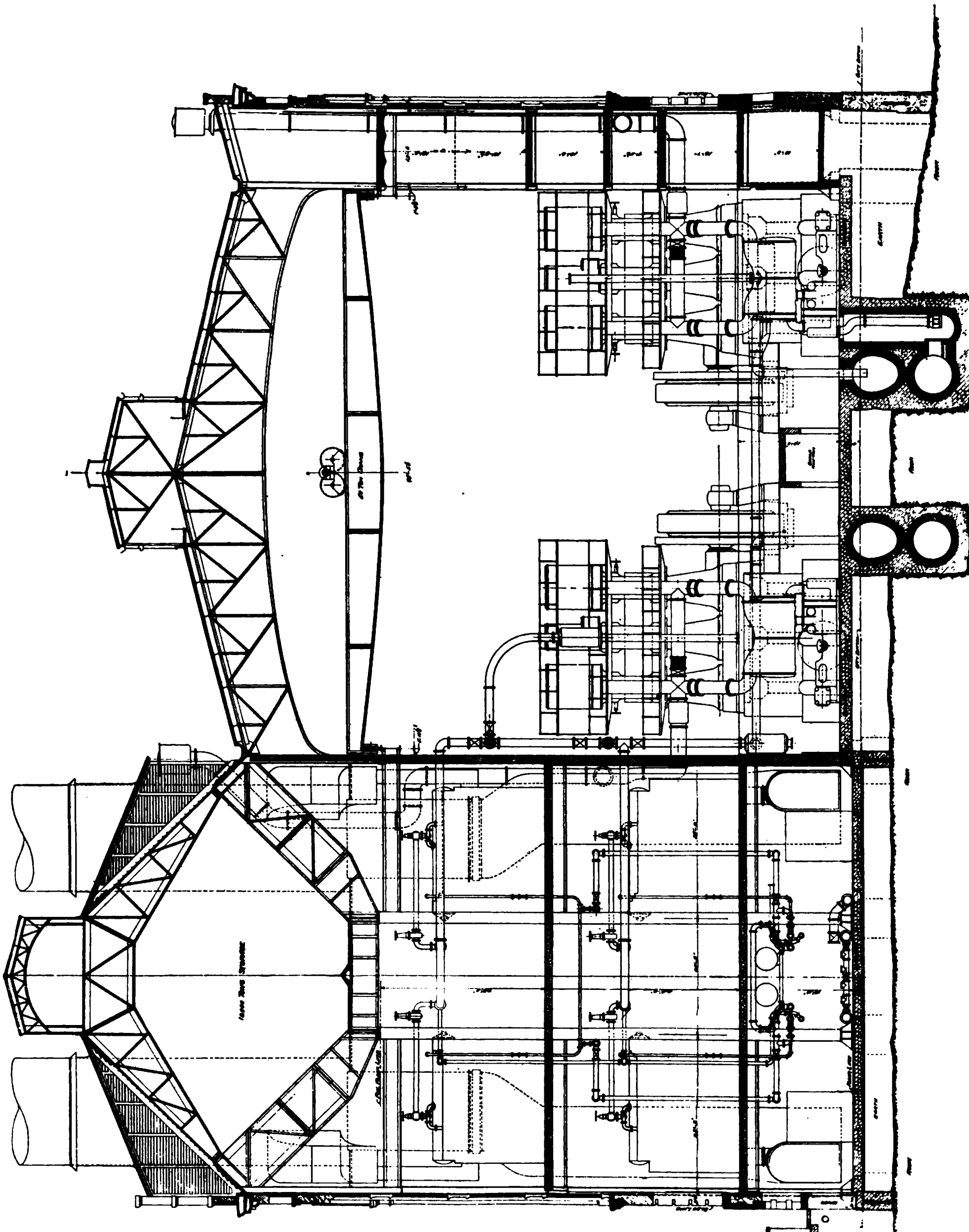


Fig. 1.—Cross Section, Waterside No. 1.

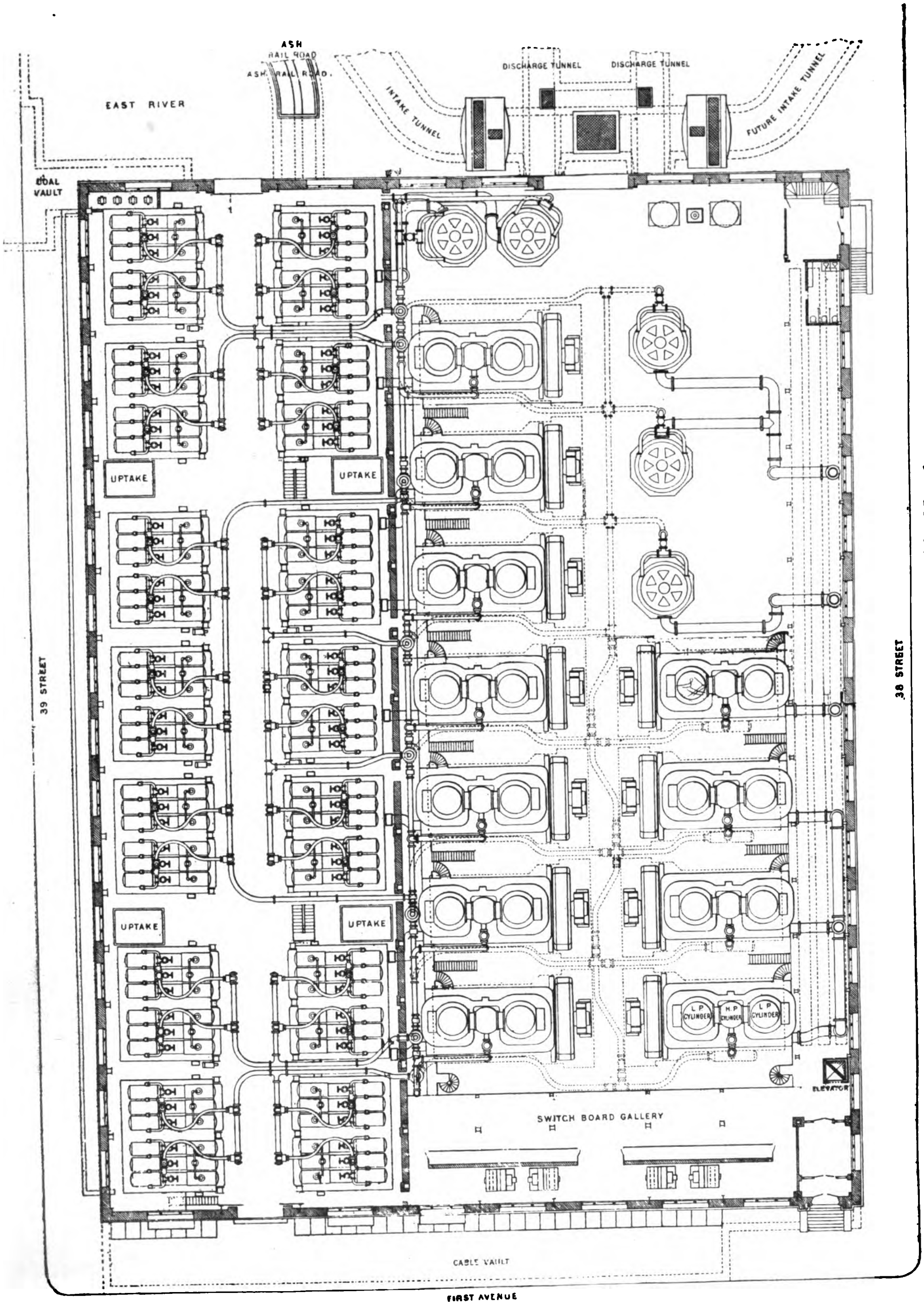


FIG. 2.—General Plan Waterside No. 1.

The building is of yellow brick, trimmed with red sandstone. The inside of the operating room is faced with pressed buff brick, with the exception of a wainscot of enamel-faced brick, 14 ft. high, running around the entire room. The floor is of cast-iron plates, and the roof, 116 ft. above, has a glass monitor, giving abundant light. The boiler floor, with the exception of the cast-iron plates along the boiler fronts, is of granolithic material. The dynamos all face inward to the central passageway, their right and left-handed revolution corresponding to their position on the north or south side. The storage battery room is in the basement on the Thirty-eighth Street side. Locker rooms, lavatories, etc., are provided in liberal measure for the comfort of the employes. On the Thirty-eighth Street side, running the full length of the building, there are five galleries, the upper ones being used for storage, offices, etc., while the two lower ones afford ready access to the upper platforms of the engines. Two electric cranes, one of 50 tons capacity and one of 25 tons, span the engine room at the curve of the roof. Both cranes have a high-speed auxiliary hoist which provides for the quick handling of light weights over the whole floor.

COAL HANDLING EQUIPMENT.

Coal is received at a coal tower built on the bulkhead. The tower bucket discharges into a hopper from which the soft coal descends into the crusher, whence it is conveyed up an inclined bridge to the weighing hoppers. The coal is received in the weighing hoppers, and is then elevated to the monitor on an inclined bridge, a horizontal conveyor distributing it into the bunkers. The latter are of steel construction and have a capacity sufficient for two weeks' supply. Coal chutes descend from the bunker, each chute feeding two boilers. The bunker is lined with concrete, no coal coming in contact with the iron, and has a deflecting ridge along the bottom, which prevents the lodging of coal in dead pockets, where it might take fire from spontaneous combustion.

THE BOILERS.

The boiler room is laid out with longitudinal firing aisles, the backs of the boilers facing the Thirty-ninth Street and the division walls, respectively. The boilers are of the standard

Babcock & Wilcox type, rated at 650 hp. They are arranged in two double tier rows, one row on each side of the boiler room, 14 in each row, 28 on a side, including both floors, or 56 in all. They are 3-drum, double-deck boilers, with 6386 sq. ft. of heating surface and 110 sq. ft. of grate surface (excepting the stoker-fired boilers, which contain 115 sq. ft. of grate surface), and usually operate on 200-lb. pressure. The fire boxes on the hand-fired boilers are 8 ft. 10½ in. deep by 12 ft. 8 in. wide. The three drums are 42 in. in diameter by 22 ft. long. Each boiler contains 294 4-in. tubes, banked 14 high and 21 wide. Eight of the boilers are equipped with attached superheaters.

The stokers are of the inclined grate type. The stoker engines, six in all, are single-acting, double-cylinder, 4½ by 4-in. engines, and are located in the aisles between the batteries of boilers. They drive a line shaft which extends along the fronts of the boilers underneath the floor. This line shaft has mounted on it the sprockets which drive the stoker mechanism. The engines are connected to the line shaft in such a way that the break-down of any engine will not cripple the stoker and necessitate the taking of that boiler off the line.

The flues are of rectangular section, with a semicircular arched roof. The material is steel plate, lined, in the case of the first-tier boilers, with firebrick. The second-tier flues are unlined, but are covered with magnesia plaster. The sectional area of the flues is 73 sq. ft. This large size of flue was installed in order that as much as possible of the dust in the flue gases would be deposited in the flue in virtue of their low velocity. The stacks are each 17 ft. in diameter and 132 ft. high. The total height from the grates of the lower tier of boilers is very nearly 200 ft. The shell of the stacks is steel plate ⅝ in. thick for 44 ft., other sections of the same length being made up of ½ and ⅜-in. plate. The lining consists of 8 in. of firebrick for one-third of the height, the remainder being red brick. The lining is carried upon rings of angle iron in independent sections of 20 ft., an air space of 4 in. being left between the lining and the stack.

ASH HANDLING SYSTEM.

The ashes from both tiers of boilers are discharged from the brick-lined, steel ash hoppers under the boilers into ash cars, which run on tracks in the boiler house basement. The cars are

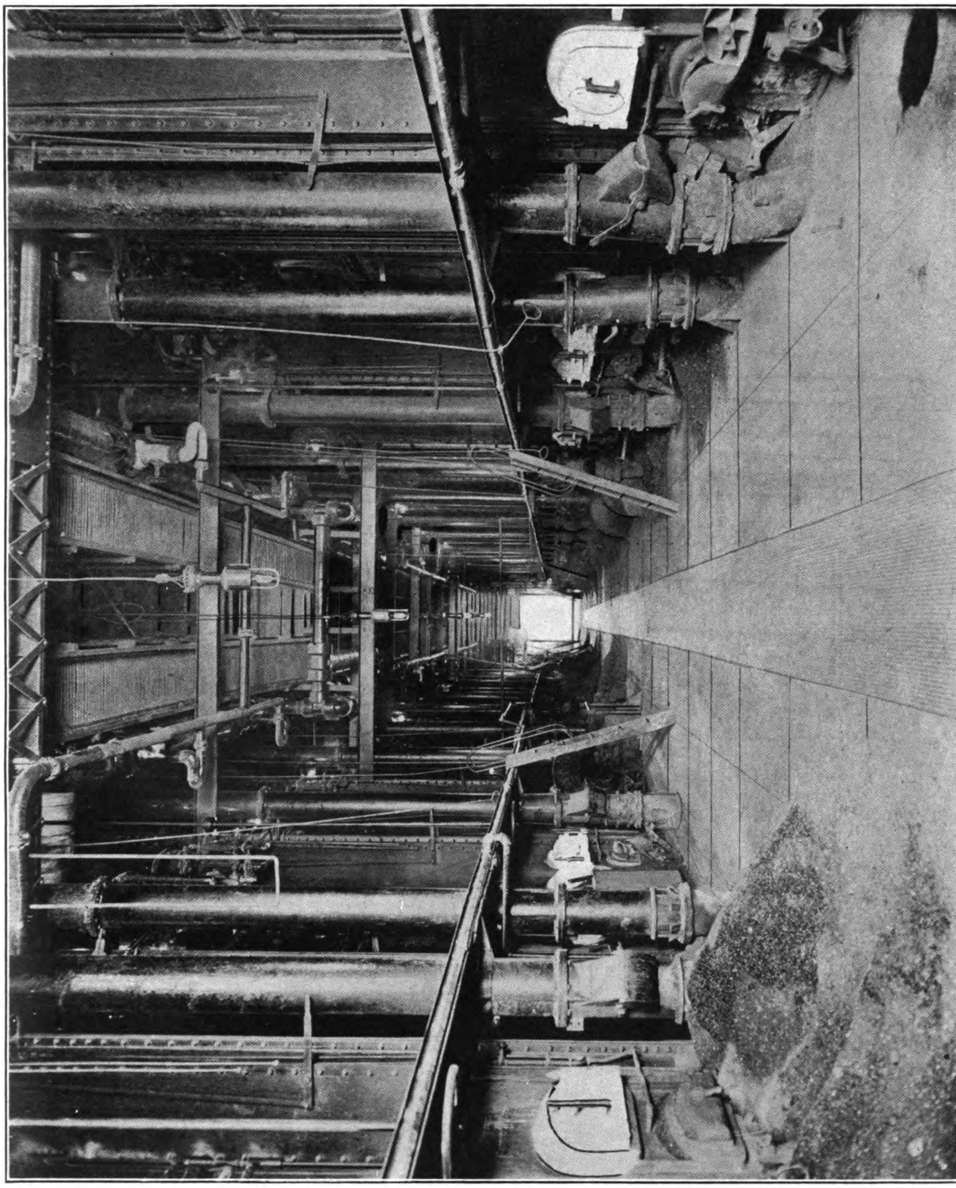


Fig. 3.—Boiler Room ,Waterside No. 1.

then pushed along the tracks to the receiving hopper in the ash-handling vault outside the building. From this point the ashes pass to a 30-in. belt conveyor, electrically driven, running in a tunnel under the marginal street, and are delivered into the hopper at the foot of the skip hoist. The skip car is then raised 100 ft. and dumped automatically into the ash pockets on the dock. From the ash pockets the ashes pass by gravity through chutes to the ash scows moored at the bulkhead.

In addition to the ash-conveying system already described, an emergency system has been installed. The ash cars can be transferred to a track running up an incline to the marginal street. The cars are pulled up the incline by means of a snatch block and electrically driven ship's windlass and pushed to the foot of the ash pockets. The body of the car is then lifted from its truck by a pivoted crane derrick mounted on the top of the ash pocket and dumped directly into the latter.

The ash pocket, which stands on the bulkhead, is built of steel and concrete and has a capacity of 29,000 cu. ft. There are six telescopic chutes on the river side for discharging the ashes into scows, and one fixed chute at the north end for discharging into carts.

STEAM PIPING.

From each boiler a 10-in. steam pipe leads to a boiler room header. These headers supply 14-in. leaders to the main ring header in the operating room. The latter are 14-in. pipe—one for each boiler floor. These two main headers are tied together by five vertical tie lines, forming a vertical ring with cross connections. From each main header 14-in. risers lead down to the engines, those from the upper header connecting with the north row of engines, and those from the lower header feeding the south engines and the turbines.

The upper floor boiler room headers are 12-in. pipe and are arranged as follows: Beginning at the west end of the building, the first two boilers on each side of the firing aisle are tied into the same leader by two 12-in. headers. The next four are tied into leader No 2 in similar fashion. In the same way the eight boilers at the east end feed leaders Nos. 7 and 8. The six middle boilers on the north side of the firing aisle feed a ring header, which connects with the main engine room header

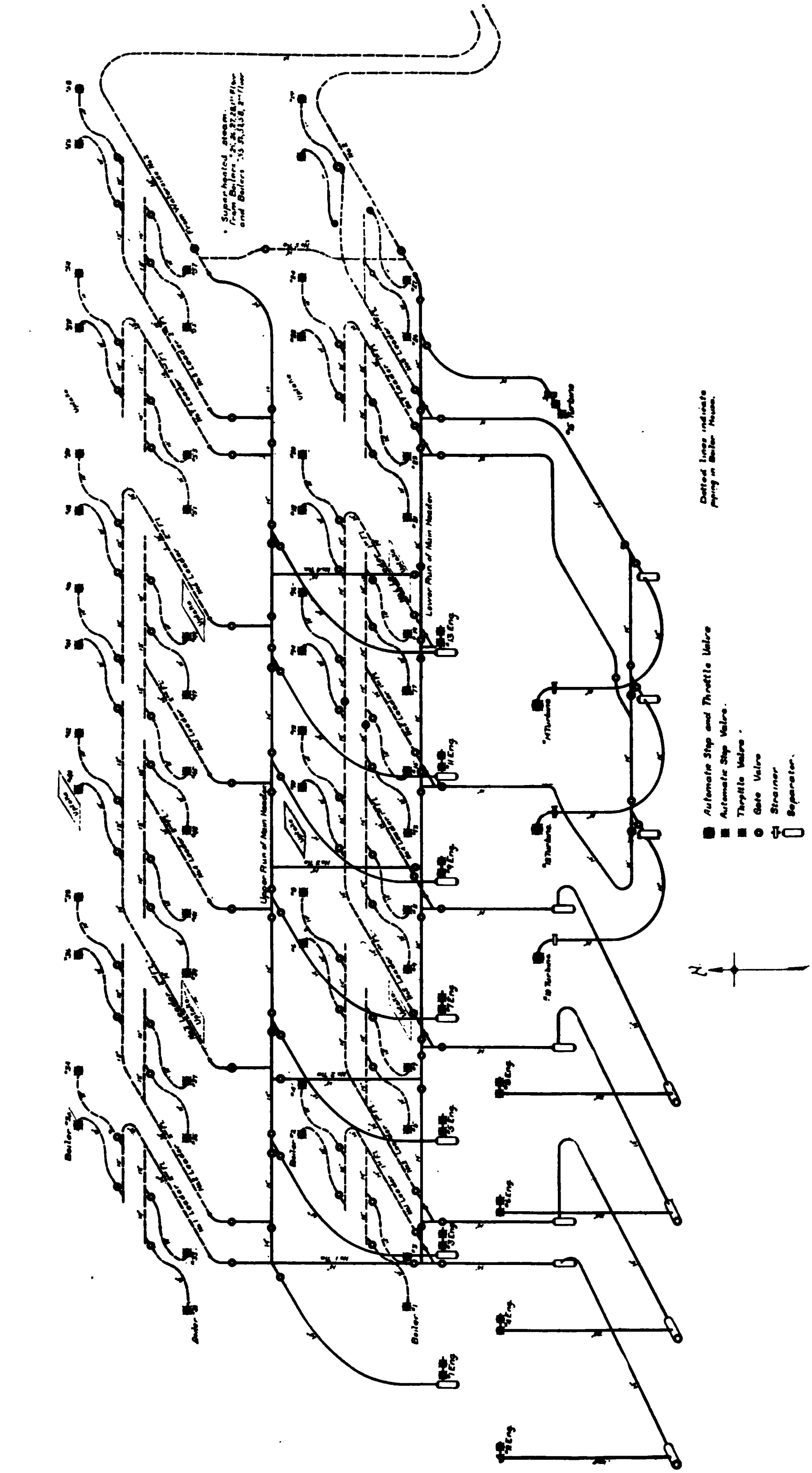


FIG. 4.—Main Steam Piping, Waterside No. 1.

through leaders Nos. 3 and 6. The remaining boilers on this floor are also arranged on a ring header similar to the last mentioned, except that the leaders, Nos. 4 and 5, are connected in the middle instead of at the ends of the header. These two ring headers have been separated in the middle since the system was installed, so that at present each half of each ring is fed by three boilers.

On the first floor the arrangement is identical, except that the middle bank of boilers has two unbroken ring headers and that all the headers are 14-in. diameter. The accompanying isometric diagram shows the general layout. All joints are ground to a steam-tight fit, no gaskets being allowed in any of the high-pressure piping. All pipe, flanges and special fittings are of the New York Edison standard for high-pressure work.

INTAKE AND DISCHARGE TUNNELS.

The condensing water is brought from the river through an intake tunnel as shown in the drawing. This tunnel is composed of two ¼-in. steel shells, with a space of 15 in. between them filled with concrete. It was made in Elizabethport and, when finished, was fitted with bow and stern bulkheads and towed to its present position.

The two discharge tunnels are built of concrete, lined with brick within the walls of the station. From the wall on the river end to the bulkhead the two tunnels are built of 12-in. creosoted timber, rectangular in section.

FEED-WATER SYSTEM.

The feed water as it is pumped into the boilers is a mixture of Croton water and water of condensation from the turbines. The Croton water from the main service meters in the sidewalk vault under First Avenue flows, under city pressure, through primary heaters on the main engines. From the heaters, at a temperature of about 110 deg., it passes over into the storage tanks in the boiler house basement, the flow being regulated by float valves in the tanks. In these tanks the feed water is then mixed with the condensed water from the turbine, which is delivered from the wet vacuum pumps and with the returns from the jacket-water system. The suction for the boiler-feed pumps is taken

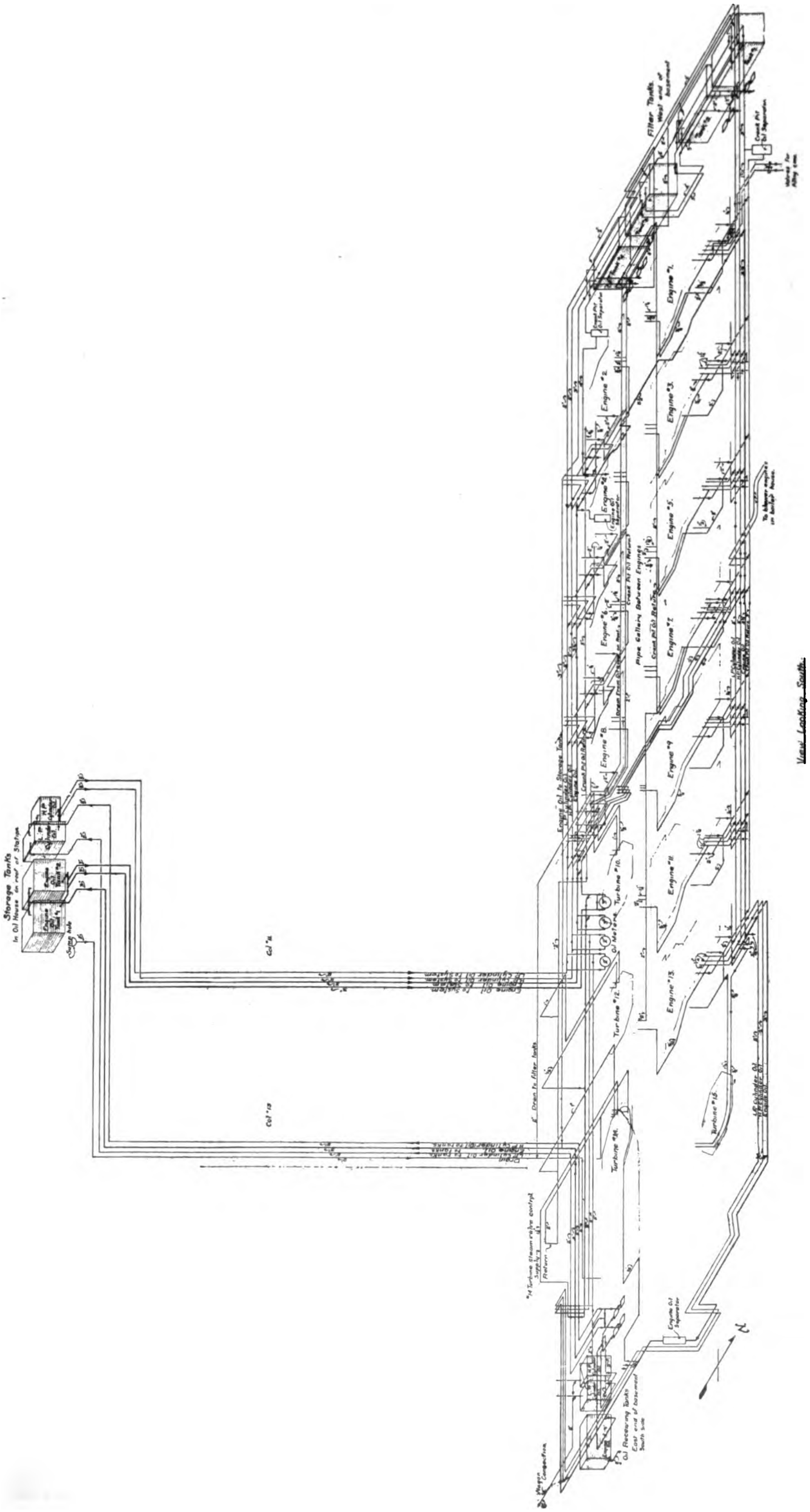


FIG. 5.—Oil System, Waterside No. 1.

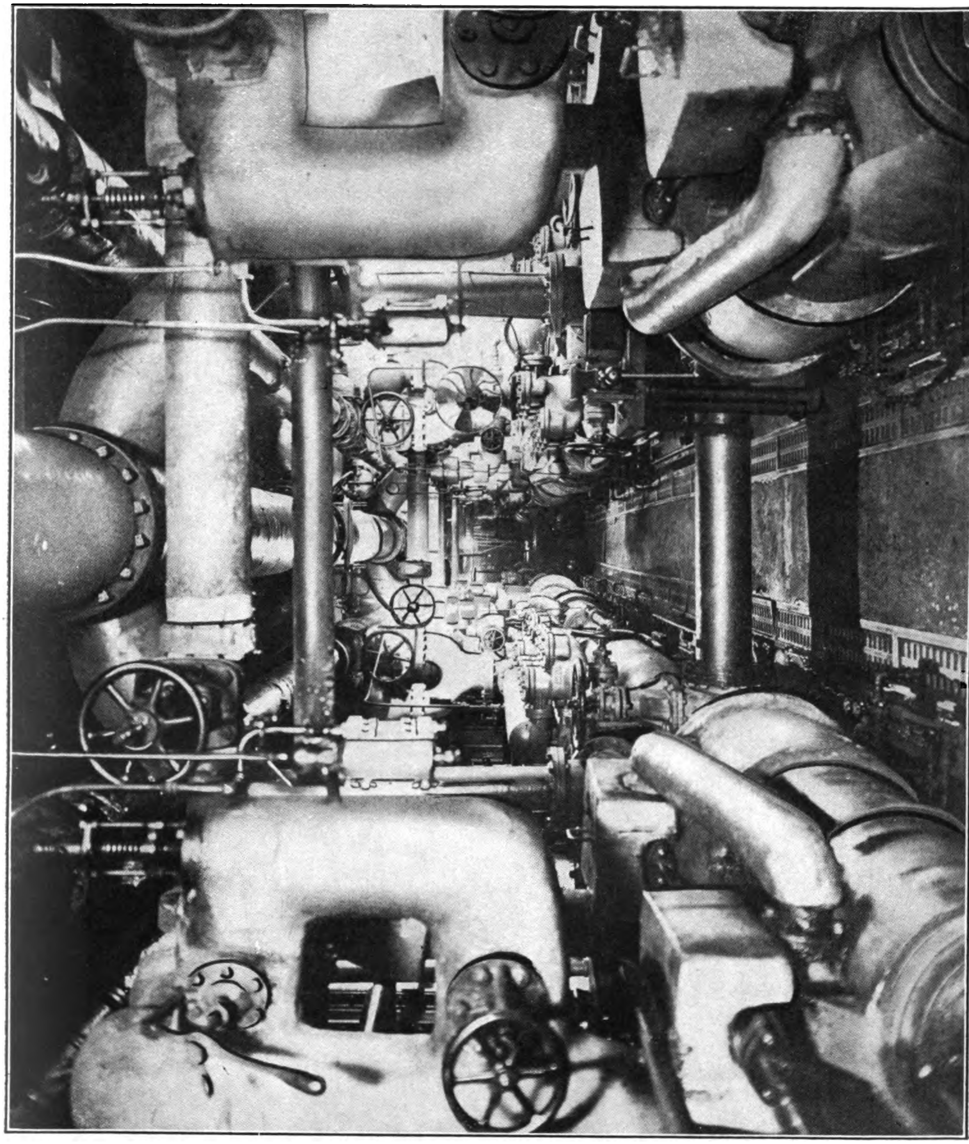


Fig. 6.—Pump Room, Waterside No. 1.

from these tanks, and the pumps force the water through the secondary heaters into the boiler feed mains and through them into the boilers. The suction lines to the feed pumps are provided with an emergency connection leading to the suction well at No. 9 circulating pump, so that the boilers can be supplied with salt water in case the supply of city water should fail at any time. The average temperature of the water in the storage tanks is 105 deg. fahr., and of the feed water proper 200 deg. fahr. The two tanks have a capacity of 23,000 gal. each.

The primary heaters are of the closed induction type, 4-pass, each containing 456 sq. ft. of heating surface. These heaters are inserted between the two outlets from the low-pressure cylinders and the condensers. The eight horizontal, compound, duplex, direct-acting feed pumps are located in the boiler house basement.

There are six secondary heaters of the 6-pass, closed type and of 4000 hp, each containing 1333 sq. ft. of heating surface. These are located under the ceiling of the boiler house basement, over the boiler feed pumps.

THE JACKET-WATER SYSTEM.

From the 8-in. Croton supply line to the primary heaters a 4-in. connection is taken for the suction to the two jacket-water pumps. These pumps are situated one in each pump room, and they discharge into 3-in. mains, which pass along the engine foundations and furnish the cooling water for the bearings and slides of each engine. The water goes into each jacket under pump pressure, but the discharge is led into an open funnel, so that the engineer can determine at all times the proper supply necessary by noting the temperature of the running water with his hand.

FORCED-DRAFT SYSTEM.

The stoker-fired boilers use natural or stack draft. The hand-fired boilers, however, have forced draft. This is obtained, on the first tier, by air ducts in two sections on each side of the boiler house, located in the ash runway or tunnels over the settling chambers. These are supplied by four double blowers direct-connected to vertical engines, one blower set located in each stack bay. The ducts are so provided with dampers that either engine can supply its adjacent section of duct or both sections on that side. The second tier of boilers is supplied by three sections of air ducts, one on each side of the boiler house under the second floor and directly over the first-tier boilers. These are supplied by eight single blowers direct-connected to vertical compound engines. Two of these are located on platforms between the first and second floors in each stack bay.

THE ENGINES.

The engines, eleven in number, are of the marine type, vertical, three-crank, with one high and two low-pressure cylinders, direct-connected to three-phase generators. The high-pressure cylinder is 43½ in. in diameter, and each low-pressure cylinder 75½ in. in diameter, with a stroke of 5 ft. The low-pressure cylinders only are jacketed, and are provided with liners. With 175-lb. steam pressure at the throttle and 26-in. vacuum, and while running at the normal speed of 75 r.p.m., the engines indicate 5200-5500 hp at most economical load, and are capable of a sustained load of 8000 hp, with an ultimate capacity at maximum cut-off (⅝ of stroke) of over 10,000 hp.

The bed plate is made in three pieces, with an extension for supporting the outboard bearing. The engine frames are of the "A" type, with a substantial bearing on the bed plate. The crank-shaft is built up in three sections, with a 10-in. hole extending from end to end. The shaft—26 in. in diameter—is supported in four bearings, the three main bearings being each 60 in. long and the outboard bearing 48 in. long. The engine, having three cranks, set at angles of 101 deg., 133 deg. and 126 deg., respectively, so as to give a uniform turning moment, does not require a heavy flywheel. A weight of 90,000 lb. in the rim, with an outside diameter of 23 ft., is sufficient to give the required steadiness of motion for parallel operation and to avoid any evidence of "beat" or pulsation in the electrical system.

The high-pressure cylinder is fitted with poppet valves, following European practice on engines of similar type using superheated steam. The low-pressure cylinders have valves of the double-ported Corliss type. The valves are driven by eccentrics from a lay shaft receiving motion from the main engine shaft by means of helical gears. European practice being followed in this respect also. The governor is driven from the lay shaft and controls both the high and low-pressure valves, the latter being also detachable so as to be adjusted by hand.

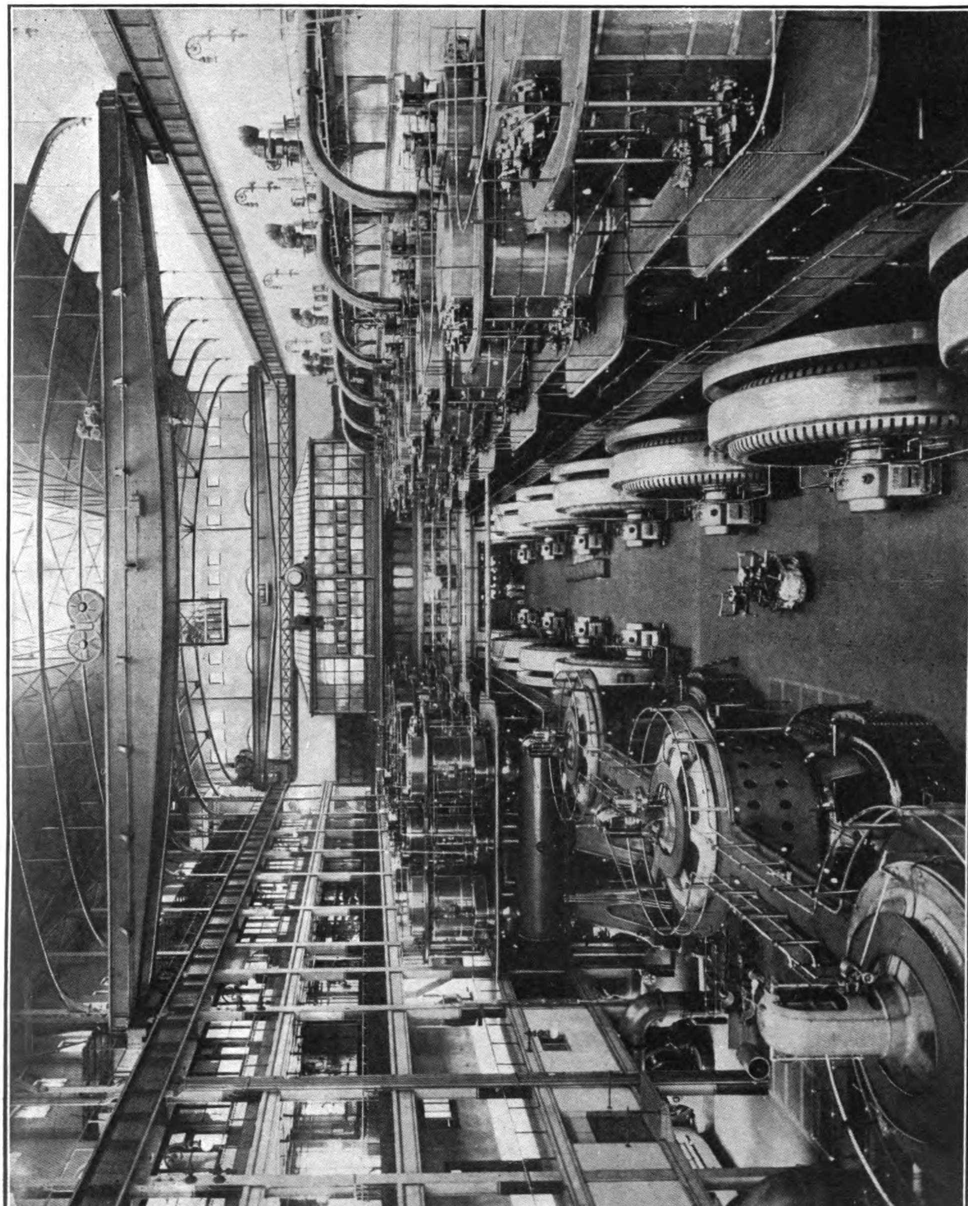


FIG. 7.—Operating Room, Waterside No. 1.

To facilitate synchronizing, the speed of the engine can also be varied from the electrical gallery by a pilot switch operating an electrical motor which shifts the weight on the governor arm.

An emergency throttle is provided, allowing steam to be shut off instantly, and this is connected to a centrifugal device in one of the crank cheeks. In passing from the high-pressure to the low-pressure cylinders, the steam traverses a reheater, the capacity of which is 220 cu. ft.

A complete oiling system is provided, the main bearings being fed by a gravity pressure system, while the cylinders, cross-heads, etc., are lubricated from sight-feed manifolds provided with pressure pumps driven from the valve motion. The oil is circulated by a special force pump, and a system of tanks is provided for filtration. Each engine has an independent air and circulating pump driven by a separate engine equipped with Corliss valve gear. The surface condensers have a cooling surface of 9200 sq. ft. Each engine is provided with an automatic relief valve in the exhaust riser, extending from each engine to the roof, where the riser is capped by an exhaust head.

Platforms at three different heights are provided, giving ready access to all the working parts of the engine; and the two upper platforms have bridges connecting from engine to engine, facilitating efficient and economical supervision and oiling. A flying bridge, which can be removed by the cranes, spans the aisle between the north and south rows of engines.

ENGINE GENERATORS.

The eleven 3500-kw, three-phase generators deliver 25-cycle alternating current at 6600 volts. They are of the revolving field, direct-connected type and run at 75 r.p.m.

The revolving field is keyed to the engine shaft and bolted to the hub of the flywheel, which is extended so as to form a heavy flange on the side toward the generator. The fields are wound with copper ribbon set on edge and give full excitation at 220 volts, thus making it possible to take the exciting current either from the low-tension board or from the storage battery in case of failure of the exciter sets.

The revolving field weighs about 130,000 lb., the armature about 125,000 lb. and the foundation plates 20,000 lb., making the total weight of each generator 275,000 lb.

TURBO GENERATING UNITS.

Besides the reciprocating engine units, there are in this station five vertical turbo-generators of various capacities.

Turbo-generators Nos. 10 and 12 are 5000-kw. vertical four-stage machines, running at 500 r.p.m. and exhausting directly after the last stage either to atmosphere through a 36-in. atmospheric valve or through an exhaust elbow direct to the condenser. Steam is admitted through a separator, strainer and automatic throttle valve on the 14-in. steam line to two 10-in. pipe bends, which carry steam to the valve chests on opposite sides of the turbines from the main steam admission. The governor is of the hydraulic mechanical type, with the usual synchronizing attachments. There are also four hand-operated valves which uncover additional nozzles between the second and third stages for overload.

Turbine No. 14 is a 5000-kw, 500-r.p.m., five-stage Curtis turbine. The condenser and auxiliaries are the same for Nos. 10, 12 and 14 turbines. The condenser is a 3-pass surface condenser, containing 19,253 sq. ft. of cooling surface. The exhaust steam is admitted at the top. At the bottom is a hot well from which is taken the wet-vacuum suction. The wet-vacuum pump is a 10 by 16 by 18-in. horizontal, direct-acting pump. The dry-vacuum pump and circulating pump are driven by the same steam cylinder. The air cylinder of the dry-vacuum pump is vertical and the steam cylinder is horizontal, while the drive to the centrifugal circulating pump is through the horizontal shaft. The circulating pump has a 10-ft. impeller, with a 24-in. discharge, and at 90 r.p.m. delivers 15,000 gal. per min. against a 35-ft. head.

Turbine No. 15 is a vertical, 8000-kw, 5-stage, 500-r.p.m. machine. Number 16 is a 5000-kw, 5-stage, 720-r.p.m. vertical turbine. These two turbines use the same auxiliaries. Turbine No. 15 exhausts into the top of its condenser through a cast-iron elbow. The cooling water is supplied by a 30-in. steam-driven centrifugal pump, the water of condensation being drawn off from the hot well by a 5-in. volute pump, driven by a steam turbine. The air is removed by a dry-vacuum pump.

Turbine No. 16 exhausts into the same condenser, connection being made through a special cast-iron elbow, a copper expansion joint and a special 3-ft. by 3-ft. 6-in. gate valve. This condenser has 5398¾-in. outside diameter admiralty, No. 18 B.W.G. tubes, 17 ft. 2½ in. long, making a cooling surface of 18,000 sq. ft., and is of sufficient capacity to take care of both turbines, running at the same time.

The step-bearing system is in duplicate throughout, obviating any chance of a shut-down due to failure in the line. Turbines Nos. 10, 12 and 14 use water for the step bearing, and for this purpose Croton water is brought in from the mains and passed through filter tanks. From these tanks it goes to the line pumps, and thence to the three turbines. The step-bearing line consists of two 1½-in. double extra-heavy hydraulic pipes and a 2-in. pipe, all in parallel. Under normal conditions the 1½-in. lines are used, but if a failure should occur on this system the 2-in. line is adequate to perform the work. This duplication is carried out in the pumps also. Two 9 by 2 by 10-in. duplex pumps furnish the pressure, but a 15-hp electric pump is in reserve and is automatically started in case the steam pumps fail to operate. The leads from the main line to the turbine are two 1¼-in. pipes, likewise arranged in parallel. Pressure is maintained constant by means of a hydraulic accumulator which, in addition, starts the electric pump, as already stated.

The manufacturers recommended in the case of turbines Nos. 15 and 16 the use of oil for the step bearings. Accordingly, these two turbines have a separate system using oil. The arrangements are practically identical with those of the water line, except that, as the required pressure is lower, the steam end of the duplex pumps is only 7½-in. diameter. The system is double throughout, as in the water-bearing line, and the same precautions against all possible failure have been observed.

GENERAL SWITCHBOARD DATA.

All of the control board switches and bus house are located at the west end of the building and occupy four mezzanines and operating floor.

The low-tension control board is on the operating room floor, the generator and automatic feeder oil switches are on the first mezzanine; the feeder selector switches and also field rheostats of all machines are on the second mezzanine; the high-tension bus and the high-tension control board occupy the third mezzanine; and on the fourth mezzanine are the generator selector switches, the bus tie and station tie switches. All of the high-tension switches are of the General Electric Company's type H oil switch, in compartments built of buff brick, with alberene stone barriers between the oil tanks.

Each switch has doors made with an oak frame and panels of ⅛-in. asbestos board. An opening is made in the panel to provide for the grounding of the oil switches; this opening is covered by a swinging door which is always kept closed.

HIGH-TENSION BUS.

The high-tension bus-bars are mounted in a bus-house built of buff brick with horizontal barriers of 3-in. fire brick, making a separation between each phase of about 3 ft., and enclosed with wired glass doors.

There are two buses, main and auxiliary; these are divided in two sections which can be connected together through an oil switch called the bus tie switch. Each bus-bar consists of four strips of 3 by ⅛-in. rolled copper secured by means of studs in porcelain insulators.

Connection is made to the bus by means of a disconnecting knife switch, the stud of which passes through porcelain insulators to the rear of the bus house, where by means of a plate, connection is made for the generator and feeder cables.

HIGH-TENSION CONTROL BOARD.

The high-tension control board is arranged different from most large alternating generating stations in that each generator is controlled from an individual pedestal, instead of the usual form of a bench board. In this way the various control wires and controlling switches of each generator are kept entirely separate.

Each pedestal contains the field break switch, the rheostat dial, the engine governor control switch, a synchronizing plug, and the three control switches for operating the two-bus selector and generator oil switches. The indicating instruments are located on a panel directly above and in front of each pedestal and are as follows: Two indicating ammeters, one polyphase watt-hour meter, one power-factor indicator, one voltmeter, one indicating wattmeter, one d. c. ammeter for field, one overload relay. It is to be noted that this overload relay simply lights a lamp, none of the generator switches are operated automatically.

The synchronizing instruments are mounted in the center on a swinging panel so that they can be turned to be seen from either the right or left. On either side of the synchronizing panel are the panels containing the instruments and control of the bus tie oil switches.

The high-tension feeder board faces the generator panels, the passage way between being left for the operator. Each feeder panel controls a group consisting of two feeders, with the necessary signal lamps, control switches and instruments consisting of one power-factor indicator, three indicating ammeters, one polyphase watt-hour meter and one bellows type time limit relay. This relay will open the automatic feeder oil switch three seconds after overload.

Provision is also made for the control of oil switches for the high-tension station tie cables. Means have been provided by which all the meters and instruments can be tested and adjusted without removal from panel or disturbing the operation.

The appearance of the rear of the panels compares very favorably with the front, all loose or unprotected wires being so well taken care of. The wiring in back of the panels has all been either wrapped with asbestos cord or covered with split pipe so that the damage from fire has been entirely eliminated.

All of the panels are of blue Vermont marble and the trim of the switchboard enclosure is of kalamein copper, making a very handsome appearance.

DIRECT CURRENT CONTROL BOARD.

The direct current control board on the operating room floor really consists of two distinct switchboards, the exciter and motor-generator, each with three sets of bus-bars which in times of emergency can be tied together. In order to avoid all danger from short circuits, the positive and negative sides are made separate switchboards, the control and operating done from a board in the center.

The exciter switchboard is fed from four 150-kw. exciters, one 30-kw compensator and a 4,000-ampere-hour storage battery, this board supplies current for the field excitation of the generators, and for the operation of the oil switches, etc.

The motor-generator switchboard is fed from four 500-kw motor-generators, a 75-kw compensator and a battery of 4,000-

ampere-hours capacity. From this board is supplied the current for light and power in the station and also to the outside three-wire system. Both of these boards are also tied in with similar boards in Waterside No. 2, thus insuring a supply of current at all times.

AUXILIARY DIRECT CURRENT SUPPLY.

The direct current supply is furnished by eight motor-generators, two compensators and two batteries. Four of the motor-generator sets are connected to the exciter board, each set consisting of a 225-hp, 6600-volt, three-phase induction motor, direct connected to a 150-kw, direct-current, four-pole generator giving a potential of 200-280 volts. The other four motor-generator sets are connected to the motor-generator board, each set consisting of a 675-hp, 6600-volt, three-phase induction motor, direct connected to a 500-kw, eight-pole generator giving a potential of 250-350 volts.

Two storage batteries are in use, of the Chloride type, known as H-29, each of 4000 ampere-hours capacity. One of these batteries has 140 cells and is connected to the exciter board, the other has 150 cells and is connected to the board. Each battery has two positive and two negative end cell switches, motor operated, of the familiar type made by the Electric Storage Battery Company.

A booster set consisting of a motor of 110 hp, 240 volts, and two generators each of 36 kw, 60 volts, all mounted on one shaft, is used to facilitate charging of the batteries and at times to carry one of the auxiliary buses at periods of light load.

HIGH-TENSION CABLES AND CABLE RUNS.

The generator cables vary in size owing to the fact that the generators are not all of the same capacity and are 500,000 cir. mils rubber insulated, 750,000, 1,000,000 and 1,500,000 cir. mils varnished cambric, insulated and lead covered.

The cables, field wires, etc., from each generator are carried through a runway in the basement formed by the foundation walls of the engines with a passage way between them. All of these cables are laid in vitrified duct carefully spaced and each duct joint is staggered throughout the run so that between each cable there is the thickness of the duct and about 2 in. of cement.

Provision is made for ventilation by means of openings along the run.

From the basement the cables are carried in duct spaced about 12 in. up to the first mezzanine to the generator oil switch; the lead-covered cable ends at this switch. From here the cables are braid-covered and covered with split duct up to the selector oil switches on the fourth mezzanine. From these switches the cables are carried to the rear bus house on the third mezzanine and by means of the knife switches previously mentioned connected to the bus.

The feeder cables are 500,000-cir. mil varnished cambric braid covered, are run as single conductors in the rear of the bus house in a similar manner to the generator cables, down in duct to the feeder selector oil switches on the second mezzanine and 250,000 cir. mils down to the automatic feeder oil switch on the first mezzanine. From these switches the feeder cable is triplex varnished cambric insulation $\frac{5}{32}$ in. around each conductor, and $\frac{5}{32}$ in. around the three, lead covered, and is carried down to the vault by means of duct or pipe to the vault; the run across the vault to the manhole is made on the underside of an angle with the angle leg down. This type of construction was used to permit of the ready inspection, repair, or removal of any damaged cable.

A tie is also made between the high-tension bus in Waterside No. 1 and the bus in Waterside No. 2; this will permit of one station being shut down and its feeders supplied from the other station during periods of light load. The connection of this tie to the main and auxiliary bus is made through a disconnecting knife switch and then through two oil switches on the fourth mezzanine.

The cables are single-conductor 1,500,000-cir. mil with $\frac{5}{32}$-in. varnished cambric and $\frac{5}{32}$-in. rubber insulation braid covered. These cables are laid in vitrified duct, each joint staggered and laid up with 1 in. cement between ducts, and 5 in. cement between any iron work.

The run is made on the roof of the fourth mezzanine through the second floor boiler room suspended from the ceiling beams and on a bridge crossing Thirty-ninth Street, Waterside No. 1 to Waterside No. 2.

SYSTEM OPERATOR AND SIGNAL SYSTEMS.

The entire control of the high-tension system is in charge of the system operator. This operator bears the same relation to the system that the train despatcher does to a railroad. He signals to the boiler room what boiler capacity will be needed in the next fifteen minutes, signals to the engine room just what engines will be required, tells the regulator what particular feeder is to be thrown in or out, and signals to substations just how much load is to be carried on each high-tension feeder.

In order that this operator can keep in touch readily and quickly with all the different parts of the system as previously outlined, a description of the methods used may be of interest.

The signal to the boiler room is one that displays numerals which indicate the horsepower of boilers that will be needed in the next fifteen minutes. The signalling to the engine room is done through the regulator, who blows a whistle and at the same time the number of engine is displayed on the west wall of the engine room. At each engine is a signal stand, by means of which various signals are displayed to engineer, and there is also mounted a frequency indicator called a speed indicator which is of assistance in synchronizing.

At the system operator's desk there are telephone plugs by means of which he can call any one of the substations, four public phones and one phone which is always free for outgoing calls. This phone system is installed in duplicate and can be operated from another place if anything happens at the desk.

There is also an emergency substation signal system used that is similar to a fire-alarm system in operation. By means of this system signals are sent out to all the sub-stations telling them just exactly what to do and when to do it.

He has in front of him a map showing each sub-station. This map is kept tagged so that the load of each feeder at each station can be seen at a glance. At one side on rollers there is a larger map on double rollers which shows the route followed by each high-tension feeder and the location of each manhole.

A telautograph is also used provided to transmit messages between the high-tension and direct-current control boards. A pneumatic tube is used to send messages between Waterside No. 1 and No. 2.

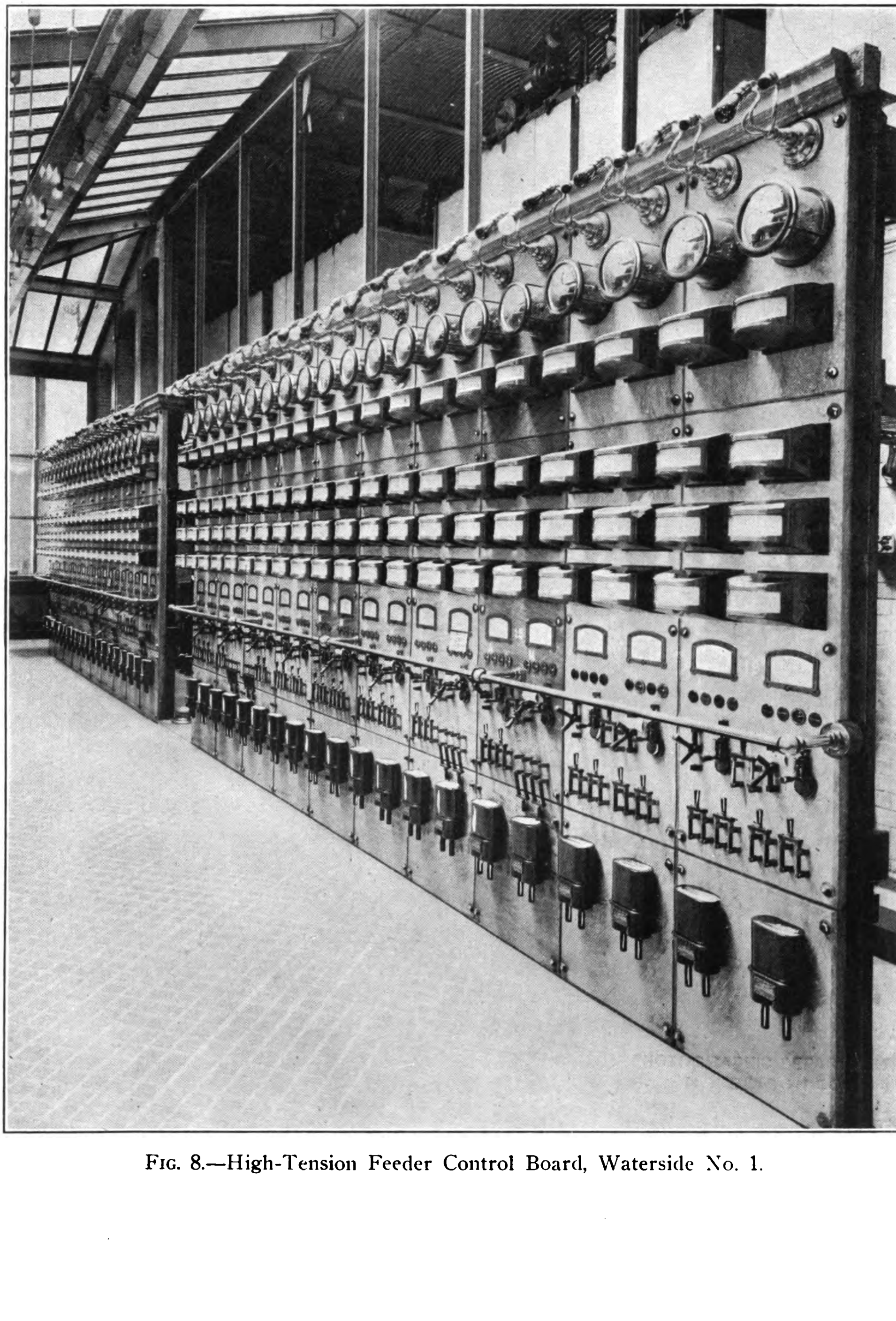


FIG. 8.—High-Tension Feeder Control Board, Waterside No. 1.

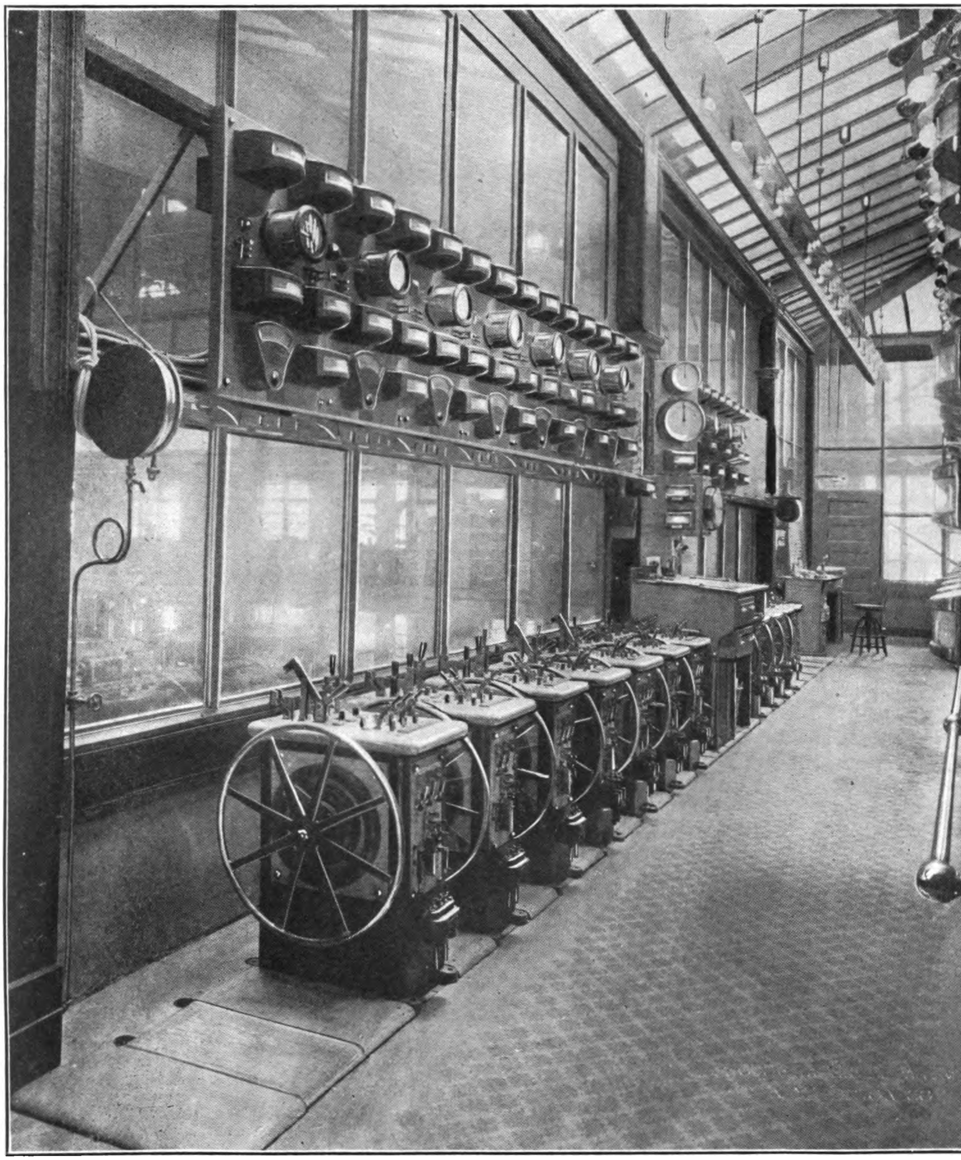


Fig. 9.—Generator Control Board, Waterside No. 1.

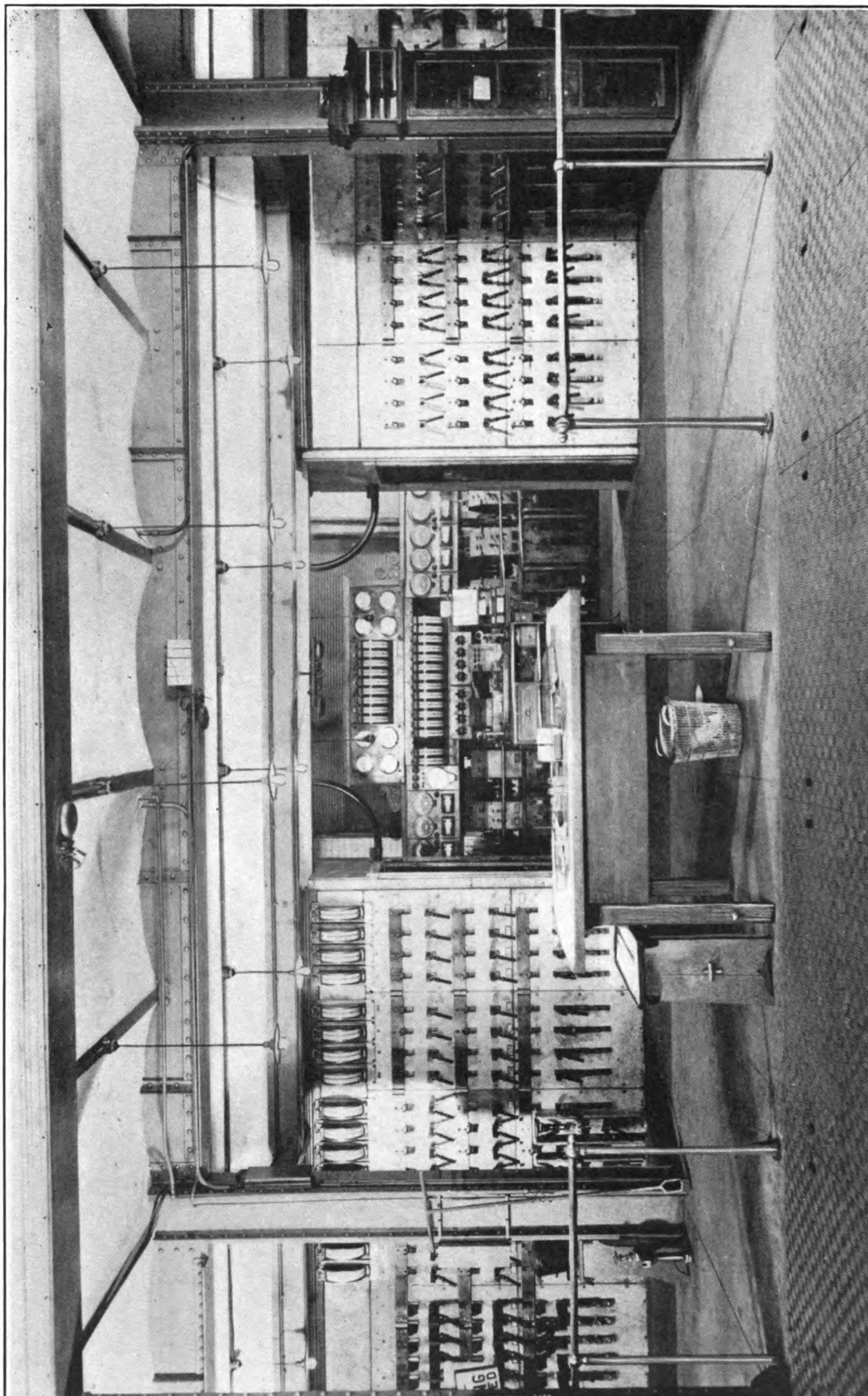


Fig. 10.—Low-Tension Switchboard, Waterside No. 1.

WATERSIDE STATION No. 2

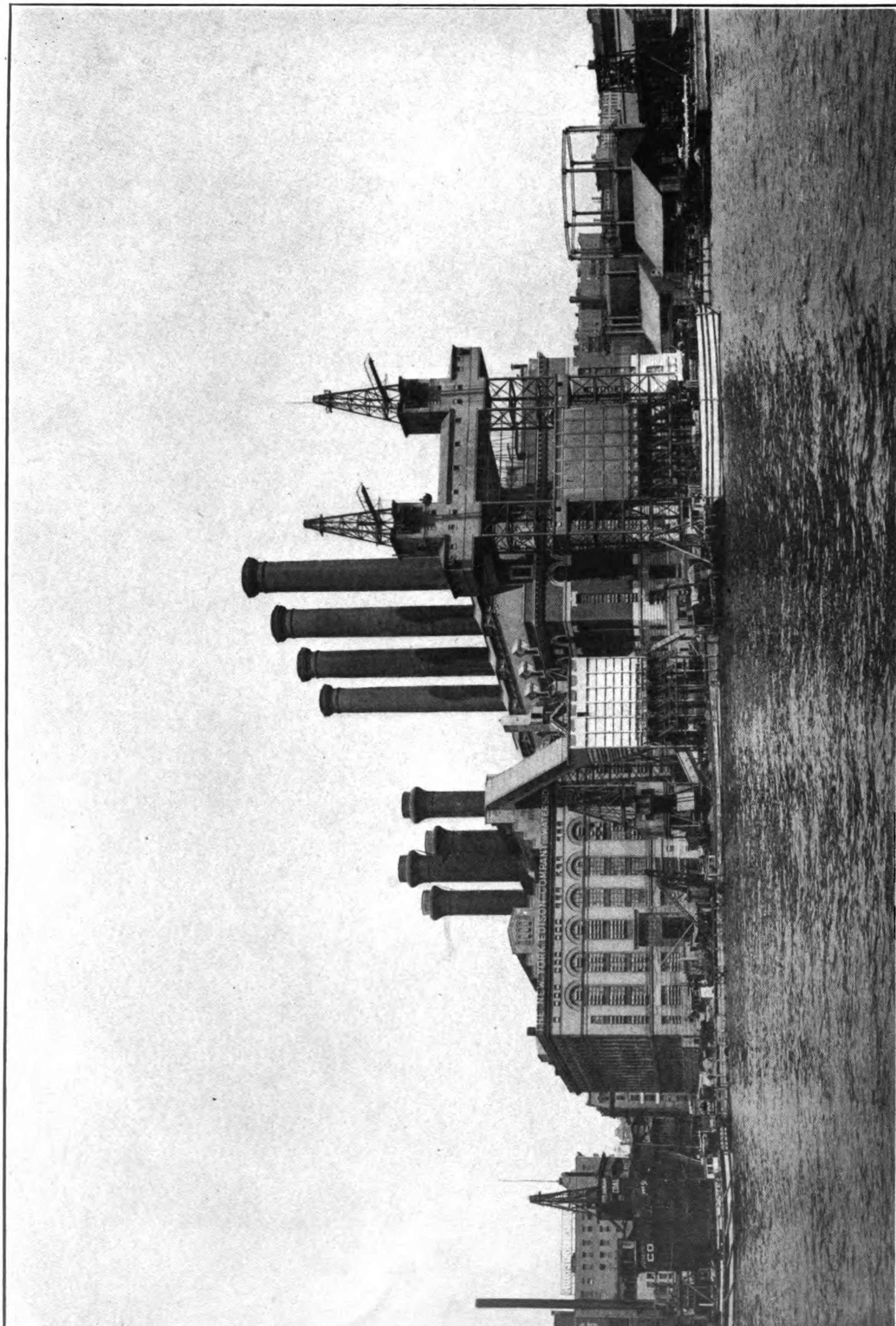


Fig. 11.—Waterside Stations, New York Edison Co.

WATERSIDE STATION NO. 2.

GENERAL.

Waterside No. 1 station was designed to satisfy the steadily increasing load on the New York Edison system at the rate then obtaining until 1910, but, as the construction proceeded, it was seen that even with the increased capacity which was obtained from the generating units the station would be at its limit after the year 1905.

It was therefore determined to construct a second station at the same center, to be known as Waterside No. 2, that location meeting the exigencies of the occasion better than any other available site on either shore of Manhattan Island. This station could be connected both electrically and mechanically with the No. 1 station, and the problems of safety, continuity of service and flexibility could be better solved by the close proximity of the stations than otherwise.

Meanwhile the two types of turbo-generating sets had been developed, and it was thought advisable in the design of Waterside No. 2 station to provide for either vertical reciprocating engines or for either or both of two types of steam turbine units of the maximum sizes then developed, thus necessitating a compromise design. The operating room was laid out to accommodate twelve 6000-kw vertical engines, sixteen 5000-kw vertical turbine units, or twelve 5500-kw horizontal turbine units. Further developments in the turbine field and certain operating conditions determined the final layout.

To carry out this plan the block adjoining Waterside No. 1, and bounded by First Avenue, Thirty-ninth, Fortieth Streets and the East River, was purchased.

The same preliminary studies as to coal supply, circulating water and load distribution, which had been factors in the design of Waterside No. 1, applied equally well to this new station.

After a great many complete studies had been made, a layout was decided upon which provided for the accommodation of 10 turbo-generator units in all, split up as follows: Two 7500-kw horizontal units, six 8000-kw vertical and two 14,000-kw vertical units and finally to provide a boiler house with accommodations for 96 650-hp Babcock and Wilcox boilers. The system of cross-firing aisles for the boiler house was adopted.

GENERAL LAYOUT.

In this station the operating room is on the north side of the building, the boiler house being on the south side, to facilitate tying the steam end of the plant to the boiler plant of Waterside No. 1, which lies just across Thirty-ninth Street to the south.

The operating room layout consists of two horizontal turbines and eight vertical turbines, arranged in two parallel rows with an aisle between. The electrical galleries run along the north wall and under them, on the main floor, are installed the exciter sets and the motor generators which supply current for the use of the station. In a vault below the main floor and extending under the sidewalk on Fortieth Street is the storage battery.

In the basement, under the operating room floor, are the turbine foundations, condensers, pumps, oiling systems and other auxiliary apparatus.

The high-tension switchboard is located at the west end of the operating room, over the entrance and connecting with the galleries along the side wall. This high-tension board is semi-circular in shape and is so placed as to enable the operator to have an unobstructed view of the operating floor.

Two cranes run on tracks under the roof of the engine room.

The boiler house contains 96 650-hp Babcock and Wilcox boilers, arranged in two tiers, 48 to a tier. The boilers are installed in eight rows across the boiler house, six boilers in a row. The boilers in each row are set back to those in the next row with the flues running parallel to the firing aisles. The stacks, four in number, are each located midway of a row and, therefore, serve 12 boilers apiece on each floor, or 24 apiece in all.

The coal bunkers occupy the top of the boiler house, and downtakes at the sides of each firing aisle feed the boilers. A glass-covered monitor runs the length of the bunker roof and contains the coal-carrying cable system. This runs through a covered bridge to the top of a coal tower situated on the river bulkhead. The ash cars run on tracks in the basement directly beneath the

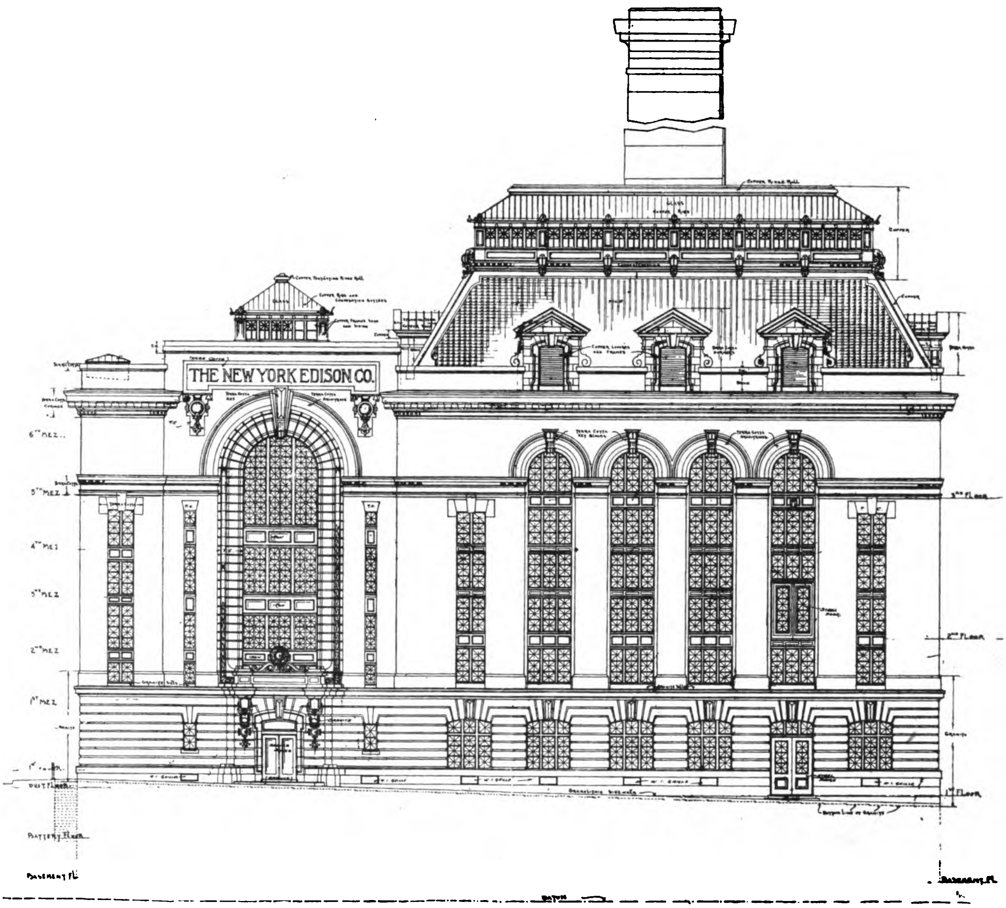


FIG. 12.—Front Elevation, First Ave., Waterside No. 2.

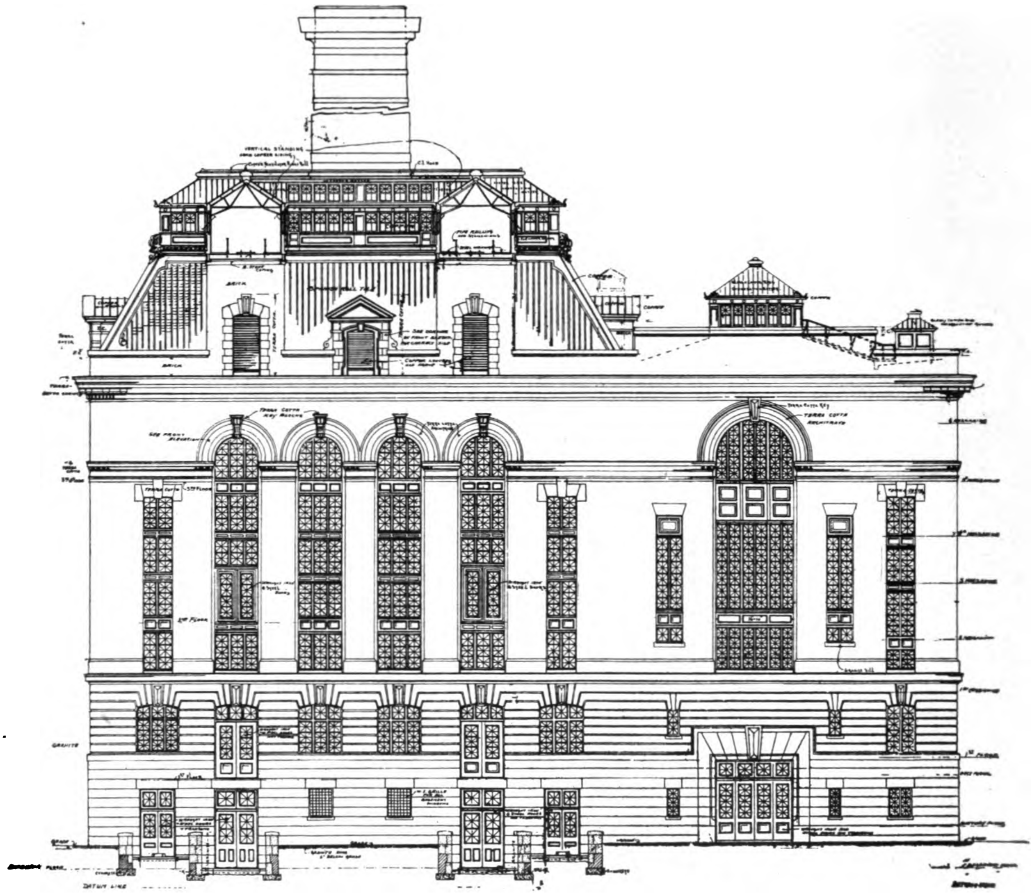


Fig. 13.—Rear Elevation, River End, Waterside No. 2.

first tier of boilers and in line with the ash downtakes from both tiers. These cars are run out to the ash hoist, which conveys the ashes to the ash-pocket in the coal tower.

THE BUILDING.

Waterside Station No. 2 is erected on a property comprising one city block, located at Thirty-ninth and Fortieth Streets and First Avenue and the East River, Borough of Manhattan, City of New York. The building covers the entire block and has the following dimensions, the ground plan of the building being trapezoidal in shape.

Dimensions.

On East Fortieth Street	347 ft.	2	in.
" Marginal street	197 "	9¾	"
" East Thirty-ninth Street	336 "	1⅞	"
" First Avenue	197 "	6	"

Area—67,478 sq. ft.

The building consists of two parts, an engine room and electrical galleries 75 ft. wide, and a boiler house 122 ft. 6 in. wide, the division wall running parallel to Thirty-ninth and Fortieth Streets. The basement floor line is at the same level for both rooms, 4 ft. 6 in. above city datum, the latter being 5 ft. 3 in. above mean low water.

The superstructure of the building is a skeleton steel frame, the walls being non-bearing.

The foundation of the building is a solid floor of stone concrete, 6 ft. thick, covering the entire area of the building, built directly on solid rock, on the west half of the building and laid on fill on the east half, with all column piers and turbine foundations going down to bedrock.

The walls are self-supporting and non-bearing, independent of the steel building framing throughout, which latter carries all floor construction and floor loads.

The building is of the modern French style of architecture, adapted to meet the general requirements of power house construction.

At the east end of the operating room basement there is an unloading platform for the reception of large pieces of machinery, this platform being served by the cranes. Access to the platform

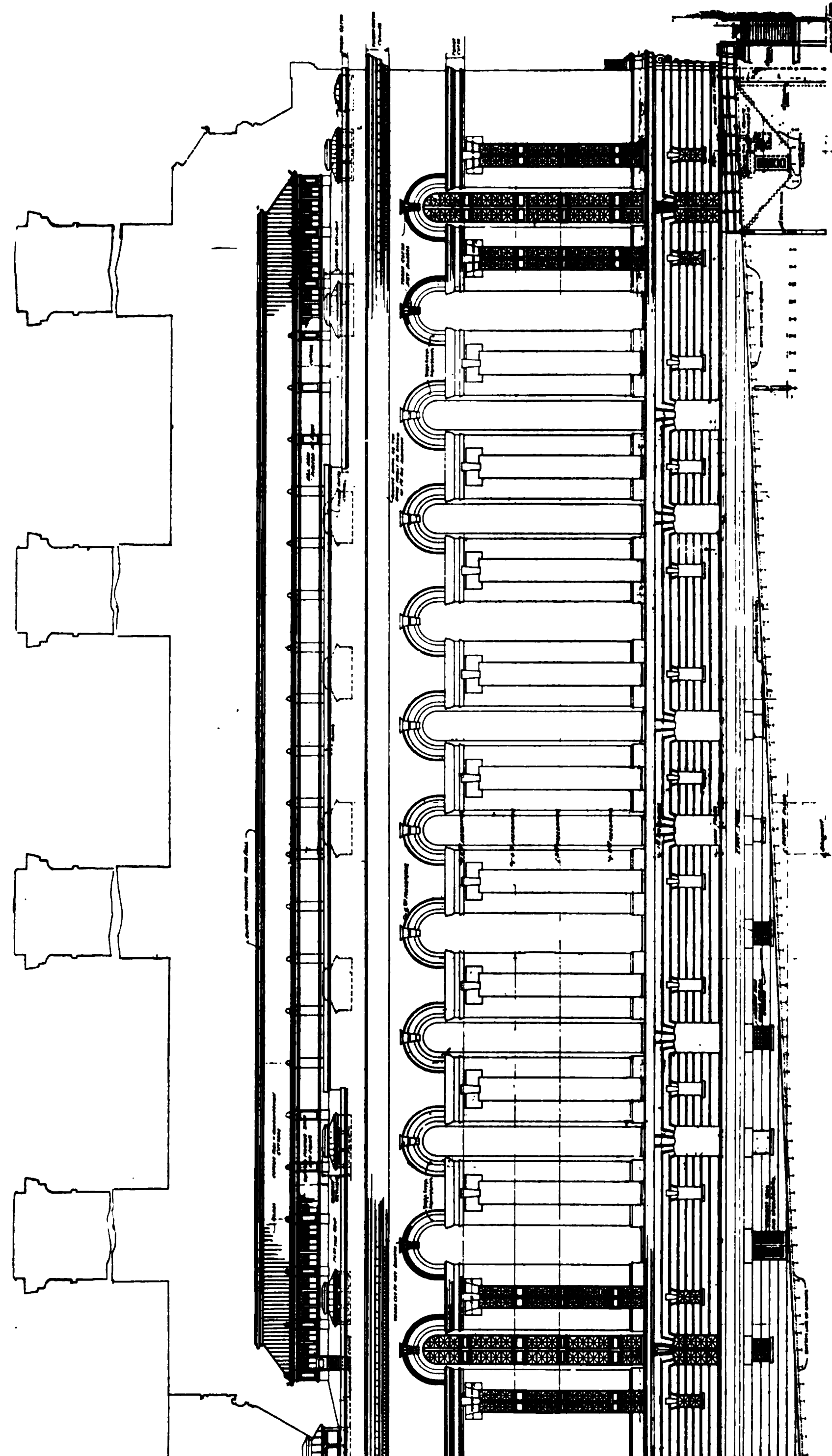


FIG. 14.—Side Elevation, Fortieth St., Waterside No. 2.

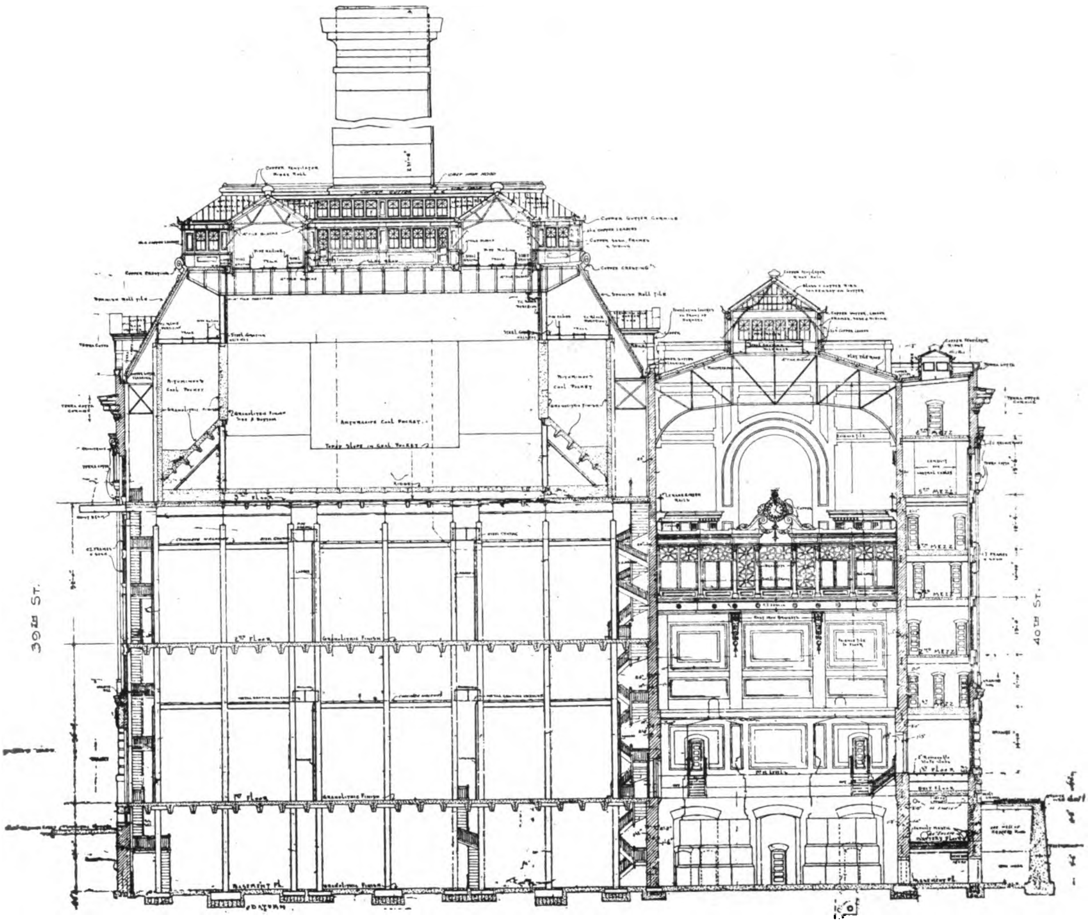


FIG. 15.—Cross Section, Waterside No. 2.

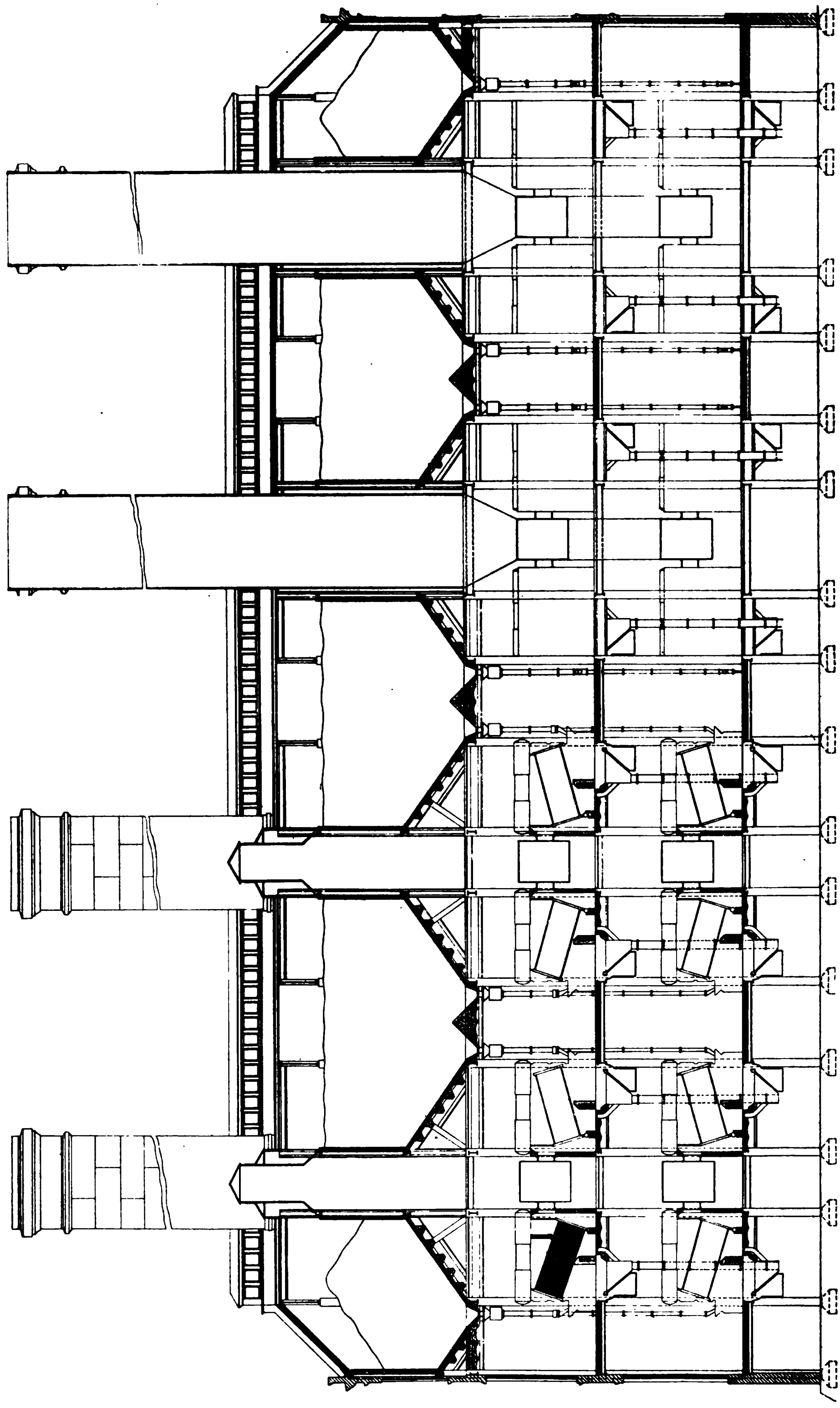


Fig. 16.—Longitudinal Section through Boiler Room, Waterside No. 2.

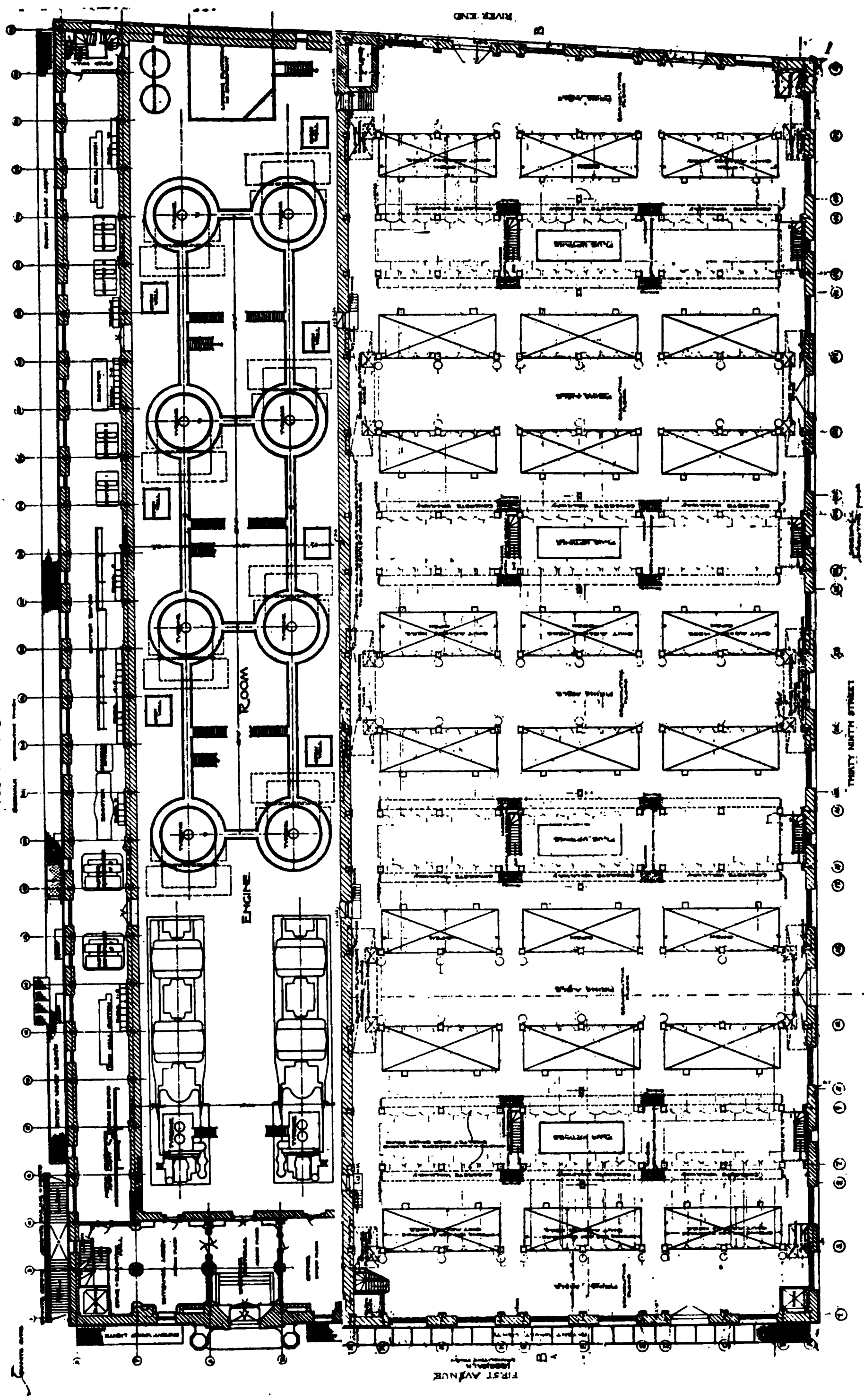


FIG. 17.—Part Plan of First Floor, Waterside No. 2.

is obtained through an opening in the wall 17 by 18 ft., protected by wrought-iron and steel doors and transoms.

The roof over the boiler house section of the building is a mansard with red Spanish roll tile, copper ridge, cresting and gutters. On the flat deck of the boiler house two monitors run from end to end of the building, having cross monitors at the First Avenue end and at each stack, the decks and monitors being covered with slag roofing.

The operating room and electrical gallery roof is covered with 1-in. flat red roofing tile. A continuous monitor in the center runs along the top of the roof of the operating room to within about 27½ ft. of First Avenue and the river walls. The ends of the boiler house monitors at the river end of the building are connected to the coal tower by means of covered bridges.

There are three electric elevators, one at each end of the boiler house; one, a passenger elevator, at the First Avenue end of the engine room. At the opposite end of the engine room there is a stair well, serving all the floors and mezzanines.

The engine room floor is constructed of removable cast-iron floor plates, relieved or recessed at the top to receive the "asbestolith" gray floor finish.

The offices are on the first floor and second mezzanine, First Avenue end.

BOILER HOUSE INTERIOR.

The basement floor, including pump rooms, compressor room, machine shop and toilet and locker rooms, on the First Avenue and Thirty-ninth Street sides, is granolithic finish. The walls are common brick, cold water painted, with removable partitions.

At the end of each firing aisle in the boiler house, on Thirty-ninth Street, and in the middle of the firing aisles on First Avenue and the river ends of the building, large wrought-iron doors have been put in for the admission of sectional parts of boilers and other machinery. Above each of these doors, on the outside at the third floor level, a short traveling hoist runway was constructed in order that machinery might be easily handled. At the level of the top of the coal pockets a grating walkway extends around the entire building, following the line of the bituminous coal car tracks. The flooring of the monitors is granolithic with wrought-iron gratings over the coal bunkers. Anthracite coal car tracks

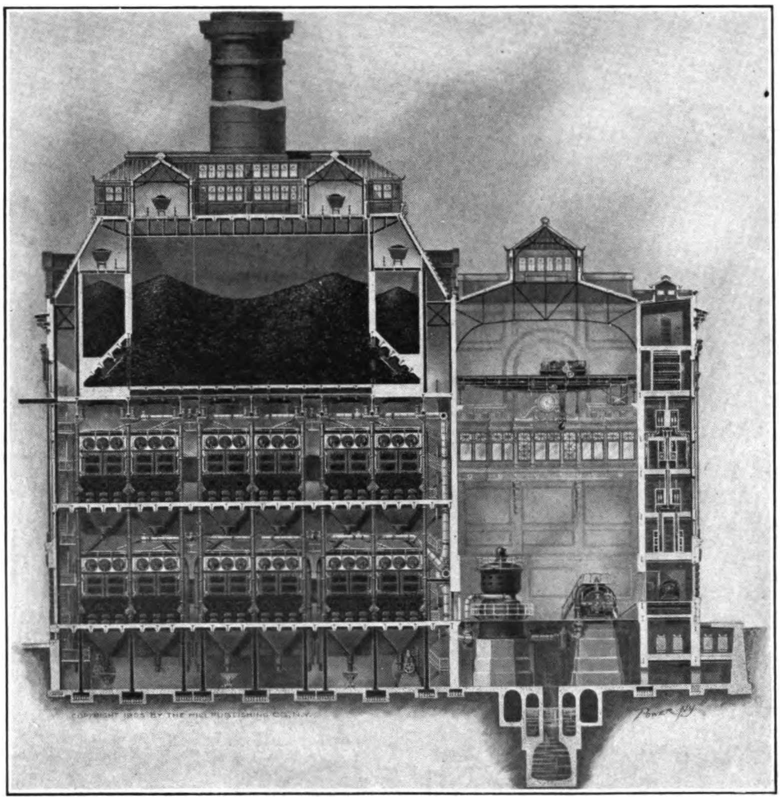


Fig. 18.—Cross Section, Waterside No. 2.

continue around the monitors and connect with the coal tower by enclosed bridges.

An oil pipe shaft is located in the northwest corner of the building and extends from the basement to the third floor, with horizontal gallery above the third floor level, extending to the underside of the oil tank room on the roof.

The floor and sidewalk arches throughout the building, including coal pocket arches, are of reinforced concrete construction.

COAL-HANDLING MACHINERY.

Bituminous coal and No. 3 anthracite buckwheat are used in this station. Both kinds of coal are hoisted from barges, moored at the dock, by two 1½-ton clamshell buckets, operated by hoisting and trolley engines in twin steel towers situated on the bulkhead. The buckets are dumped into receiving hoppers located in these same towers, the elevation of the top of the hoppers being about 187 ft. above datum. From this point the coal slides down through chutes and through a crusher, in the case of the soft coal, to cars standing on weighing track scales.

Here the filled cars are gripped to a cable system, which runs over the tops of the bunkers, the cars being dumped automatically at the desired bunker. The cars make the complete circuit of the coal bunkers, carried by the cable, which is operated by a motor situated in the south tower.

It was the original intention of the designers to dump the contents of the soft coal cars into hoppers, provided for the purpose, at the east end of the building, thence distributing it to the various soft coal bunkers by means of cars operated at a lower level on a separate cable runway. The motor and drive for this cable were situated at the east end of the building. This lower runway is, however, discontinued at the present time, the soft coal being dumped directly into the west bunker from the upper runway by means of temporary wooden chutes erected for the purpose. The west bunker is the one that supplies the stoker-operated boilers.

COAL TOWER.

Ash pockets and twin steel coal towers are located on the bulkhead. They are supported by a substantial steel frame and connected with the boiler house by two covered plate girder bridges, over which runs the cable railway. This structure has the following dimensions:

Ground plan, 25 ft. wide, center to center of columns; 105 ft. long, center to center of columns.

These towers are what is known as the two-man type, fitted with two-drum, direct-connected bucket engines; single-drum, direct-connected trolley engines; automatic buckets; hinged boom. A safety attachment has been devised to take up the shock in case the counterweight cable should break.

The coal bunkers have a capacity of about 20,000 tons, or nearly 15 days' supply. At present this tonnage is split up as follows: Hard coal, 16,000 tons; soft coal, 4000 tons.

The coal downtakes are 15-in. cast-iron pipes, bolted together, leading from special cast-iron hoppers at the base of the coal pockets to the various firing aisles, these downtakes resting on cast-iron pedestals equipped with coal valves.

METHOD OF HANDLING ASHES.

The ashes from the hoppers under the several boilers pass into ash downtakes, fitted with valves, these downtakes leading to the basement in the boiler house. They are dumped into special sheet metal dumping cars and are hauled by a storage battery locomotive, capable of pulling two loaded cars, to the foot of the ash pocket structure on the bulkhead. Here they are dumped into the loading hoppers of the ash conveyor. The conveyor lifts the ashes up about 80 ft. and discharges them into the ash pocket through a movable dumping block. The ash pocket is concrete lined and supported by the steel coal tower frames. It has a capacity of about 1800 cu. yd. Seven cast-iron hoppers and telescopic chutes, on the river side, convey the ashes to the scows. There are also three chutes provided on the marginal street side of the pocket for loading ashes into wagons.

The ash handling system is in duplicate. The second system, and the one generally used, except in cases of breakdown, is a skip hoist in place of the conveyor. Instead of dumping the ash cars at the foot of the coal tower structure and hoisting the ashes to the ash pocket by means of the bucket conveyor they are dumped into a hopper located in a pit just outside the river-end building wall. From this point they are lifted directly to the

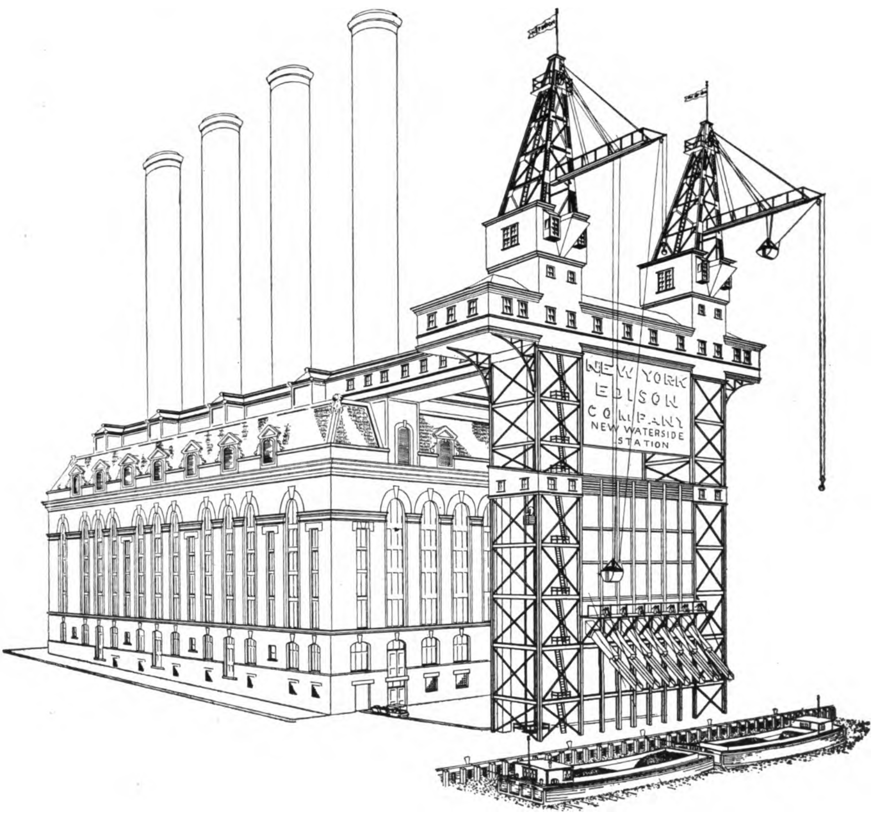


FIG. 19.—Coal Handling Machinery, Waterside No. 2.

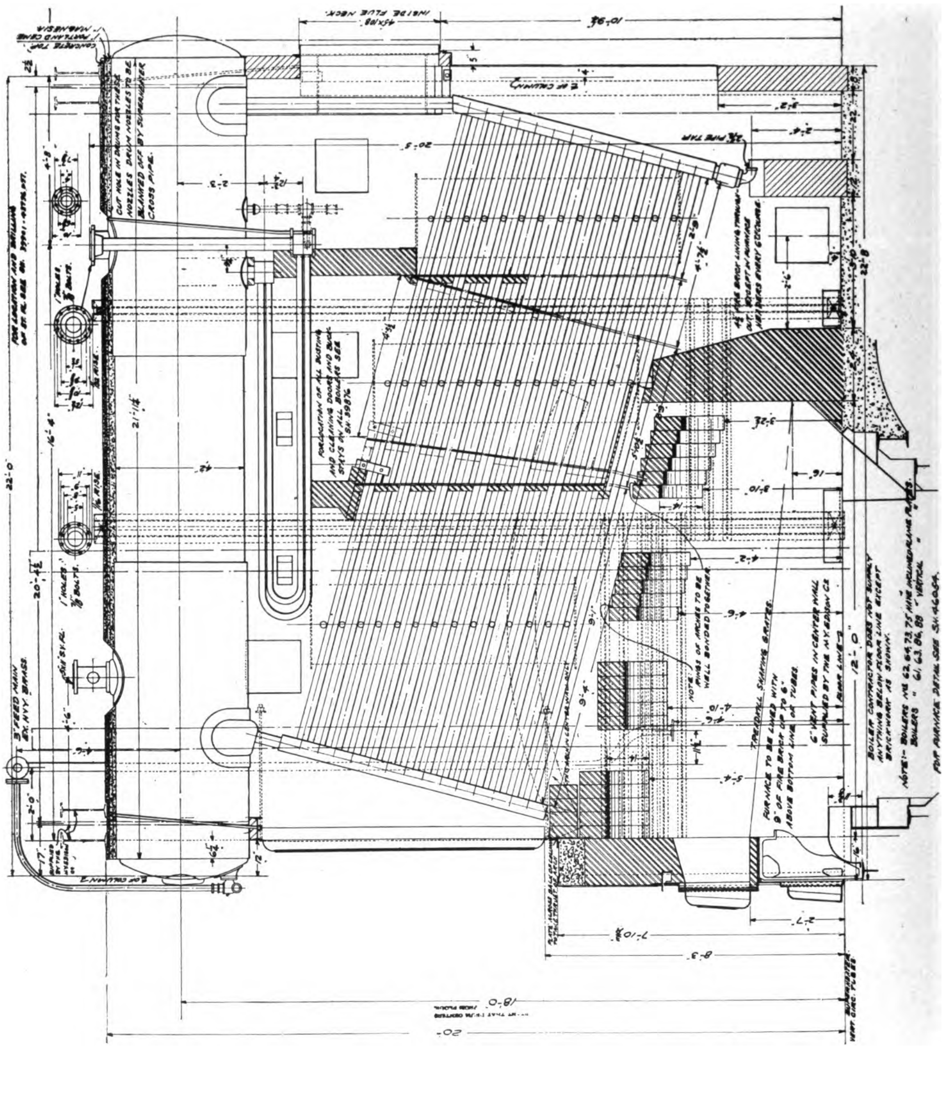


FIG. 20.—Section of Babcock & Wilcox Boiler, Waterside No. 2.

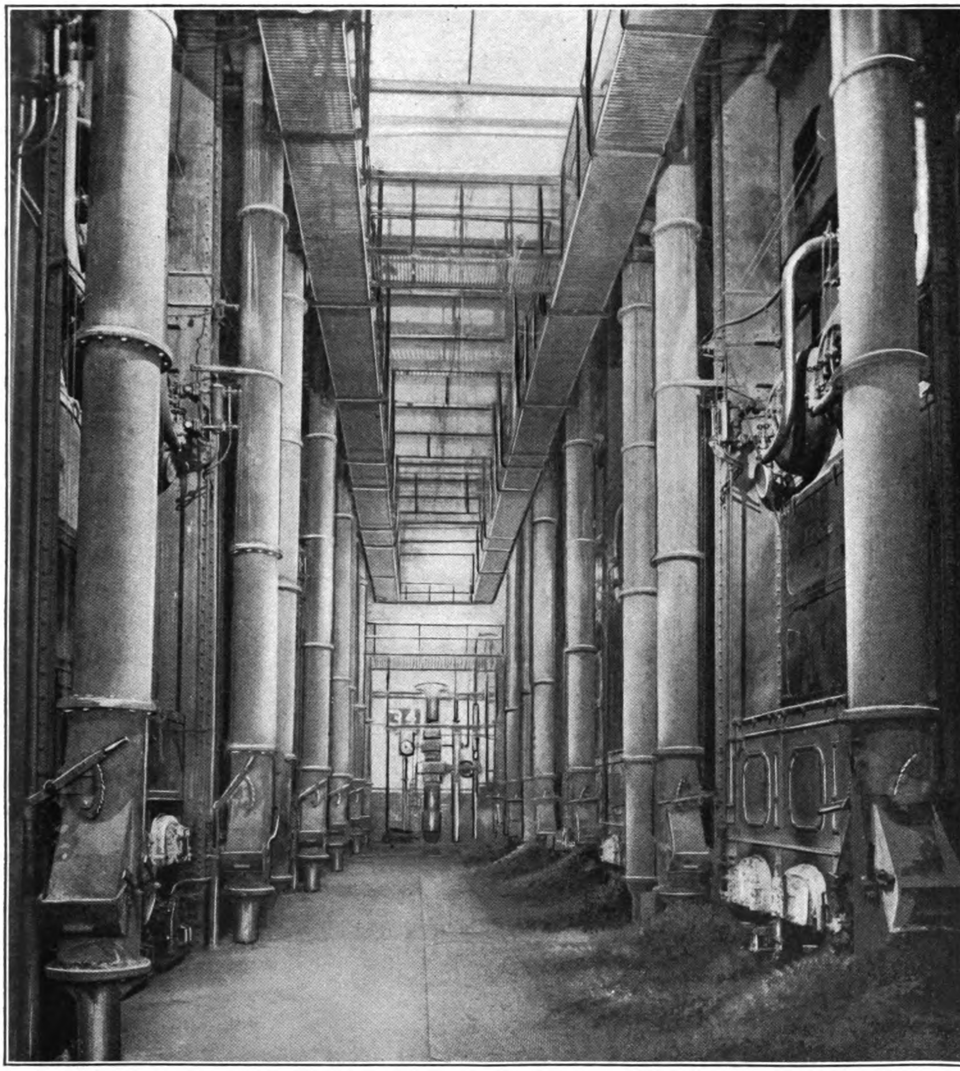


Fig. 21.—Boiler Room, Waterside No. 2.

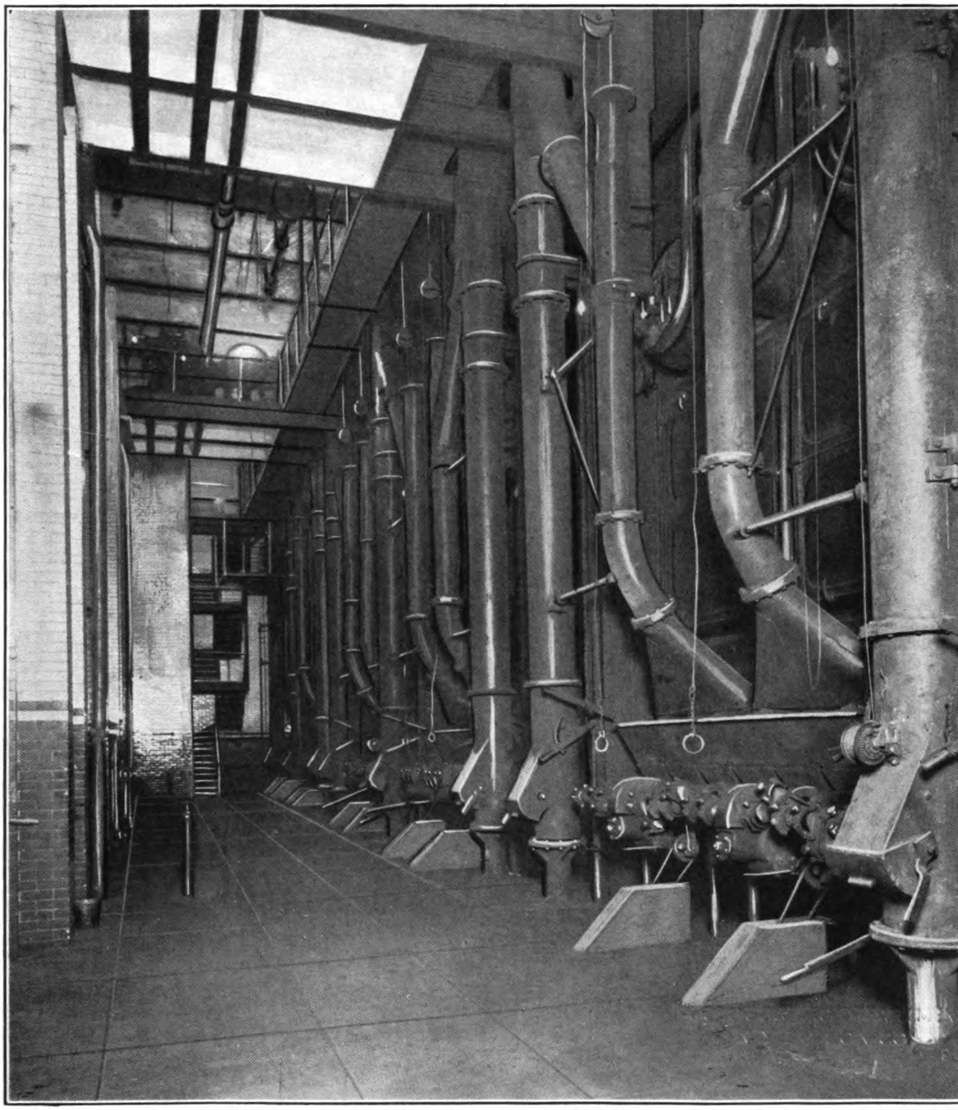


Fig. 22.—Boiler Room, Waterside No. 2.

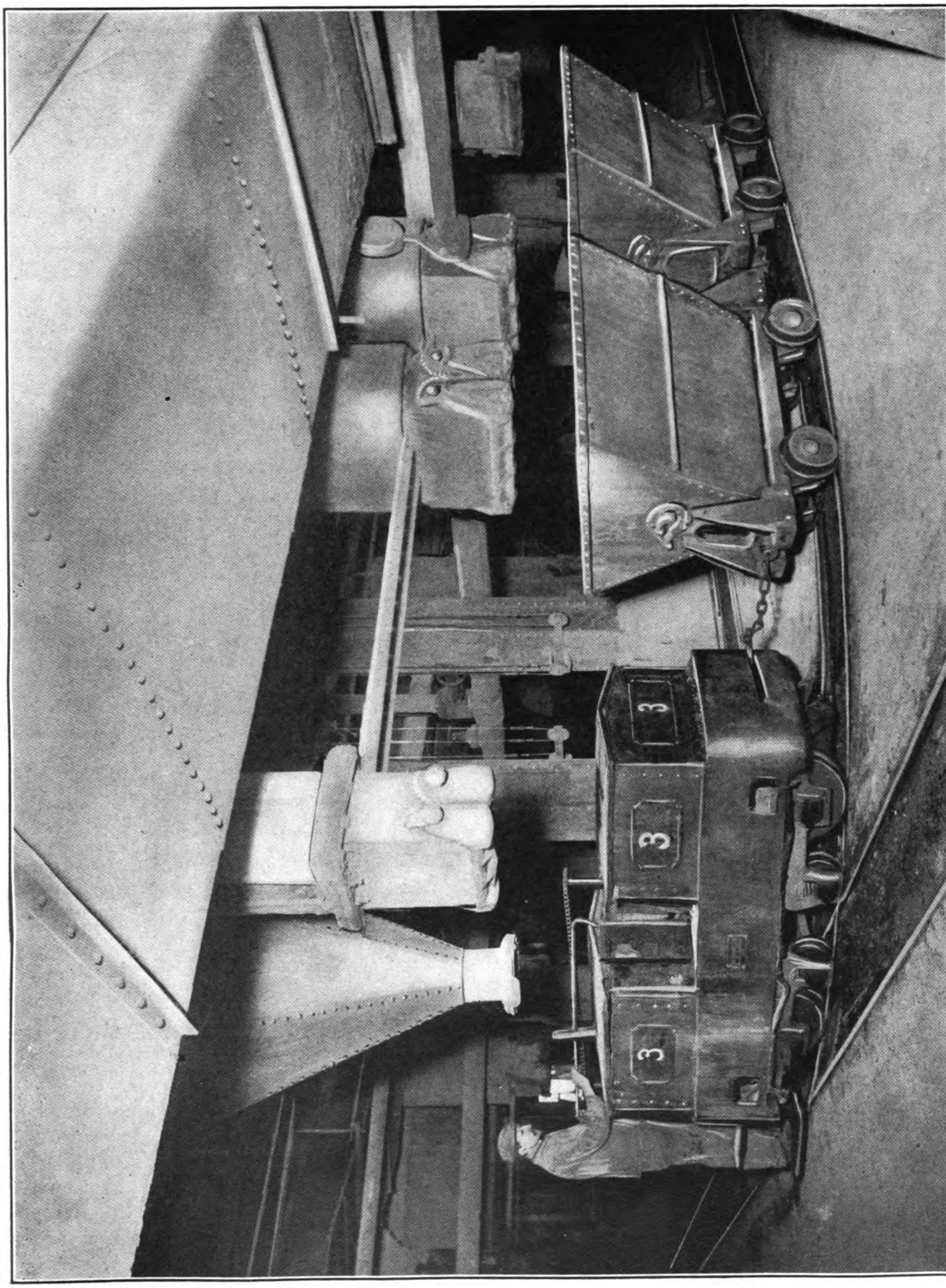


Fig. 23.—Ash Conveying System, Waterside No. 2.

ash pockets by means of a double skip-hoist, operating over an inclined runway. The bridges supporting this runway are housed with corrugated iron sheething.

The capacity of the loading hopper is about 450 cu. ft. The cut-off gates at the bottom of the hopper are operated by a system of levers from the basement floor level.

THE STEAM GENERATING PLANT.

The steam generating plant is composed of water-tube boilers, whose weight is carried directly by the steel frame of the building. The settings are faced with white enameled brick, lined with firebrick. The fronts are gray cast iron of standard design and the rear wall brick and sheet steel. The tops of the drums and spaces between are covered with a cinder fill on top of 1-in. magnesia and 1 in. of Portland cement mortar; the cinder fill being finished with a top dressing of concrete makes a perfectly flat deck on top of the boilers.

The boilers are Babcock and Wilcox, 650-hp, with three 42-in. drums. The tubes are 4-in. outside diameter, 18 ft. long, arranged in a bank 21 tubes wide by 14 tubes high, making 294 tubes in all. The boiler is nominally rated at 6386 sq. ft. of heating surface with an attached superheater containing 760 sq. ft., which superheats the steam 100 to 125 deg. fahr. above the temperature due to the pressure carried.

The boilers are designed for a pressure of 225 lb. per sq. in., but 190 lb. is the usual working pressure.

The size of the firebox is: 12 ft. 7 in. wide by 7 ft. 6 in. deep on 13 boilers; 12 ft. 7 in. wide by 12 ft. deep on 36 boilers; 12 ft. 7 in. wide by 9 ft. 6 in. deep on 42 boilers.

The boilers with fireboxes only 7 ft. 6 in. deep are equipped with automatic stokers.

The hand-fired boilers are equipped with shaking grates adapted to burn No. 3 buckwheat anthracite coal. Thirteen of the boilers in this station are equipped with gravity underfeed stokers, which have an inclined fuel bed made up of air-perforated tuyeres, coal being fed into the furnace by rams, operated by cranks and a worm-gear train.

Each section of boilers is fitted with sheet-iron flues and uptakes. Heavy cast-iron dampers, with roller bearings, permit the closing of the first tier uptake from the second tier. There are, as stated previously, four steel stacks, one for each section.

Height above finished third floor, 231 ft. 8 in.; height above first tier of grates, 297 ft. 1 in.; height above second tier of grates, 261 ft. 1 in.; diameter, 21 ft., outside at top; 22 ft. 6 in. outside at base.

Each stack is built up of ¾-in. to ⅜-in. steel plate, about 7 ft. to each course. To every third plate there are riveted two angles for supporting the brick lining. This lining consists of 1 in. of concrete and 4 in. of common read brick throughout the entire height. Each stack has ten vertical 6 by 4-in. angle stiffening posts riveted to the inside of the shell.

The stacks rest on plate girders, transmitting the load to the building columns. The wind and sway bracing is attached to the bunker framing. The stacks are further provided with 18-in. steel ladders on the outside, broad hand-railing, cast-iron crown piece and grating walkway around the top.

Ash hoppers are provided under the grates of each boiler. These consist of a heavy cast-iron frame bolted to the steel framing. To the lower portion of these castings are bolted the sheet metal hoppers, brick-lined. From the bottom, cast-iron downtakes lead to the basement, where ashes from the first-tier boilers are received directly in the ash cars; ashes from the second-tier boilers are received in cylindrical sheet-metal ash receivers, red brick-lined.

Air for combustion is admitted from the forced draft systems to the ash-pit through a special casting, bolted to the ash hopper, the area of the air intake being approximately 25 sq. ft.

THE FORCED-DRAFT SYSTEM.

The system in use in this station is that of producing the draft over the fires by the stacks and then forcing air under pressure into the closed ash-pits and slightly overbalancing the draft, thus maintaining a draft over the fire of about two-tenths of an inch. This prevents most of the inrush of cold air over the fires and the leakage of cold air through the boiler settings and reduces initial strains on the boilers, due to fluctuating temperatures in the fire-box, to a minimum.

To effect this there are eight independent air ducts under each tier of boilers, running north and south; each duct takes care of

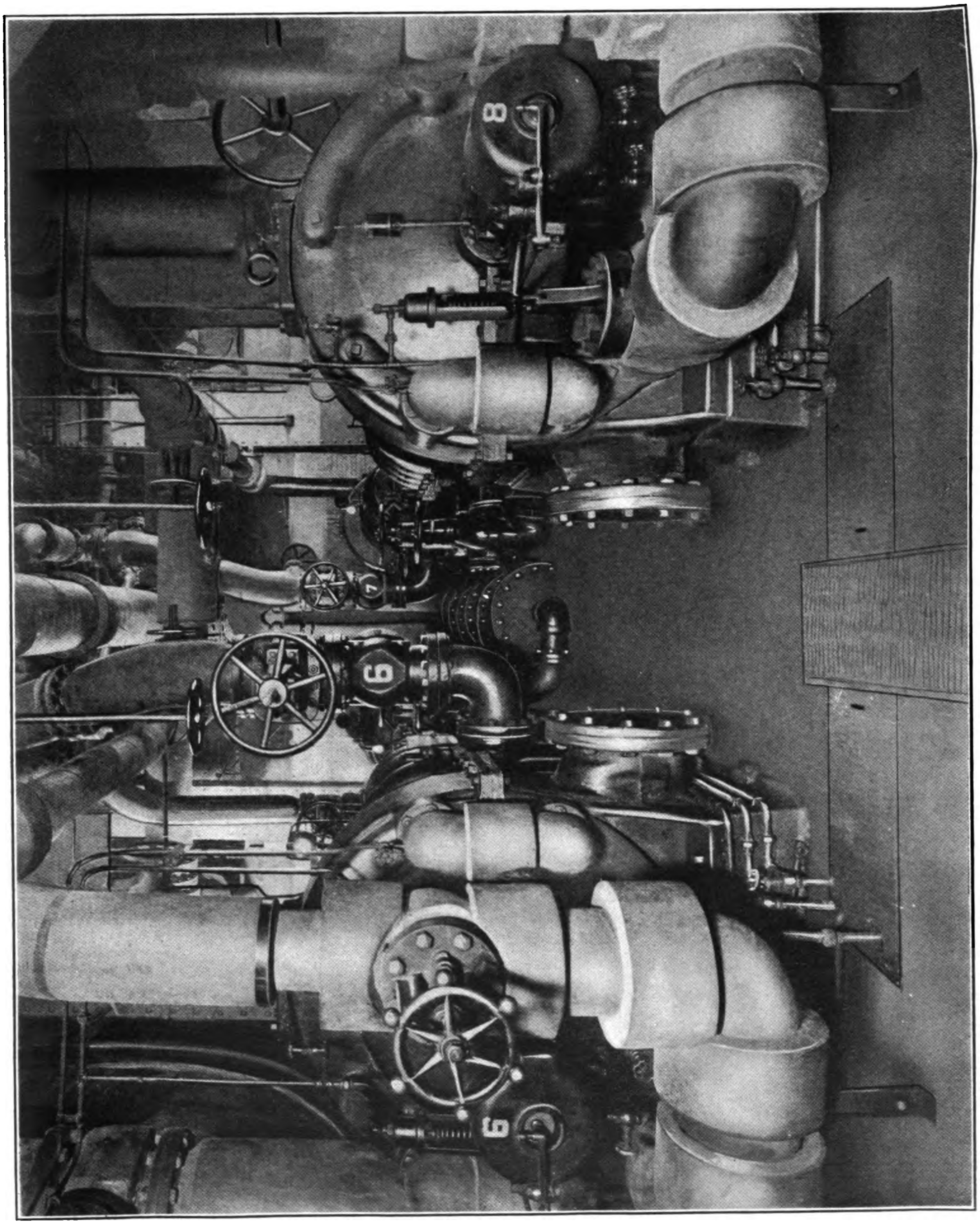


FIG. 24.—Turbine Driven Boiler Feed Pumps, Waterside No. 2.

six boilers and is supplied with air at each end by blowers, direct-connected to vertical engines. Each duct is provided with three dampers, one at the center of the duct and one at the outlet of each fan. In each duct are provided six ash-pit connections to the boilers, with dampers and mechanism for controlling the same from the fire-room. These ducts have a cross-sectional area of about 30 sq. ft., and an approximate length of 100 ft. The fans are rated at 90,000 cu. ft. of air per min.

THE FEED-WATER SYSTEM.

The feed-water system of this station is extremely novel and interesting, embodying as it does several new departures from the well-trodden paths of standard feed water system design.

The supply is made up of two parts, the condensate from the surface condensers, and the make-up water from the Croton mains. Croton water is received from the regular city service through two 12-in. mains, one on the Thirty-ninth Street side and one on the First Avenue side of the power house. The water from the main on the First Avenue side, after passing through a fish trap and check valve, is measured by four 6-in. trident crest water meters. The discharge is reunited in a 12-in. main and distributed through 8-in. branch pipes to the open heaters in the two feed water pump rooms, the flow being regulated by means of a float in each heater, which operates a Mason balanced regulating valve.

The water from the 12-in. main, on the Thirty-ninth Street side, is metered and delivered into the heaters in the same manner.

All the above piping is protected from freezing, where exposed by 2 in. of hair felt and a jacket of 10-oz. duck.

The condenser hot-well returns are collected in a 12-in. header, located in the boiler rooms along the north wall; from here a 14-in. pipe, branching to two 10-in. lines, leads the returns into the top of the heaters in both pump rooms. This flow is maintained by the turbine hot-well pumps, which are designed to operate on a 25-ft. discharge head, the amount of water delivered to each heater being controlled by a float operating a balanced regulating valve.

One of the novel features in this system is the use of turbine-driven, multi-stage centrifugal feed pumps. Each pump room

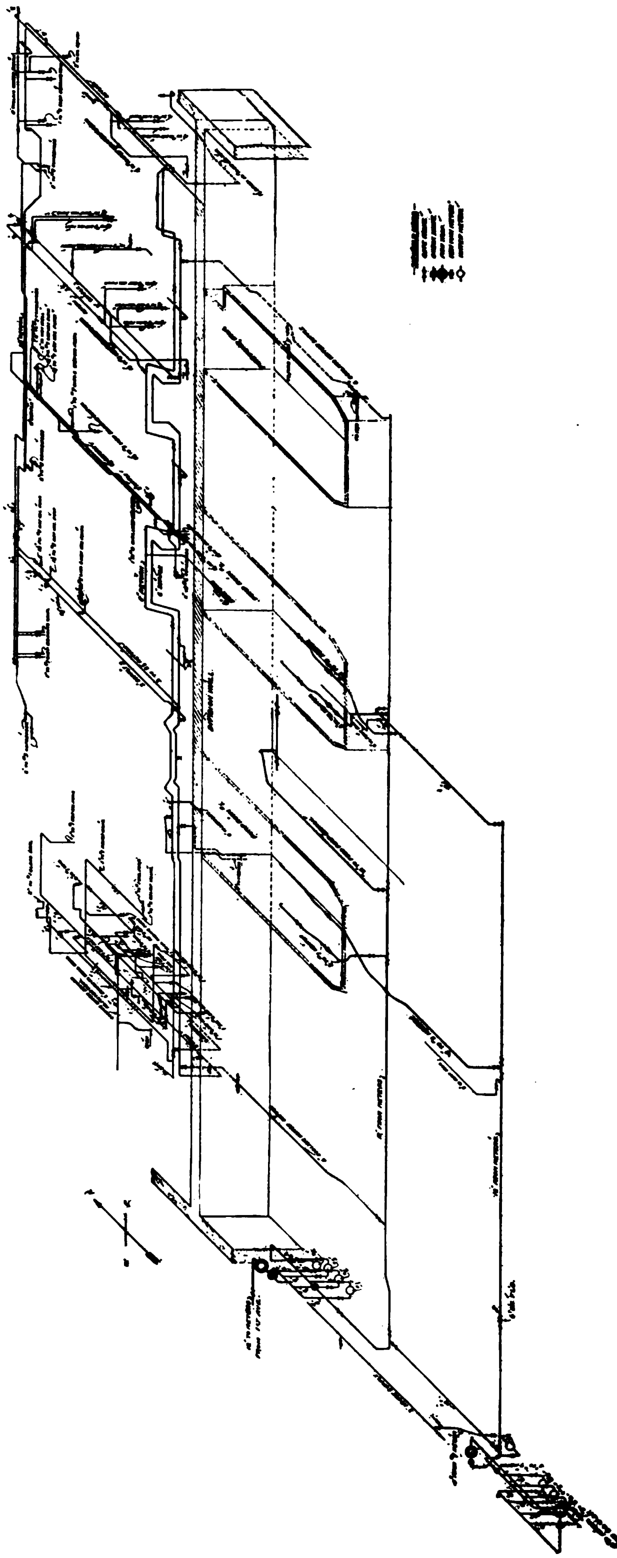
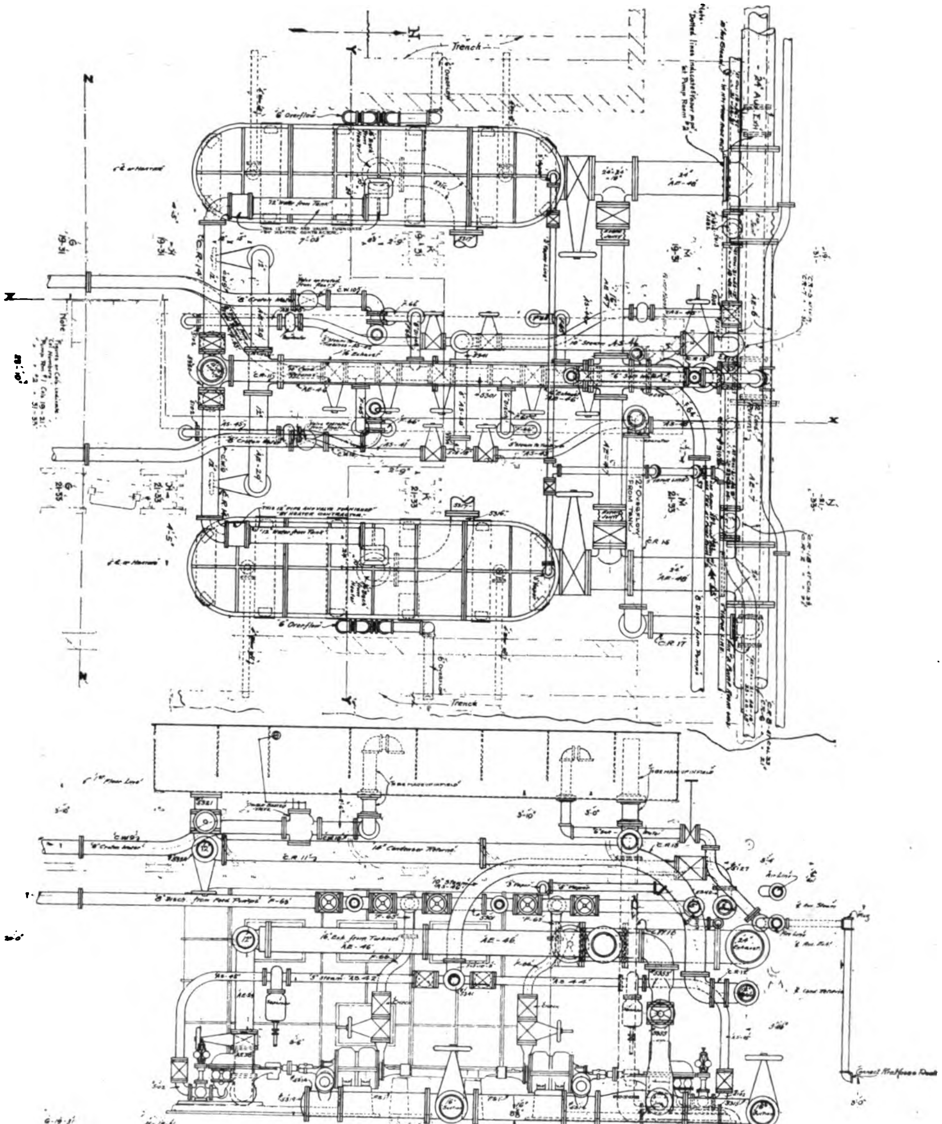


FIG. 25.—Croton and Cooling Water Lines, Waterside No. 2.



SECTION X-X

FIG. 26.—Layout of Pump Rooms, Waterside Nos. 1 and 2.

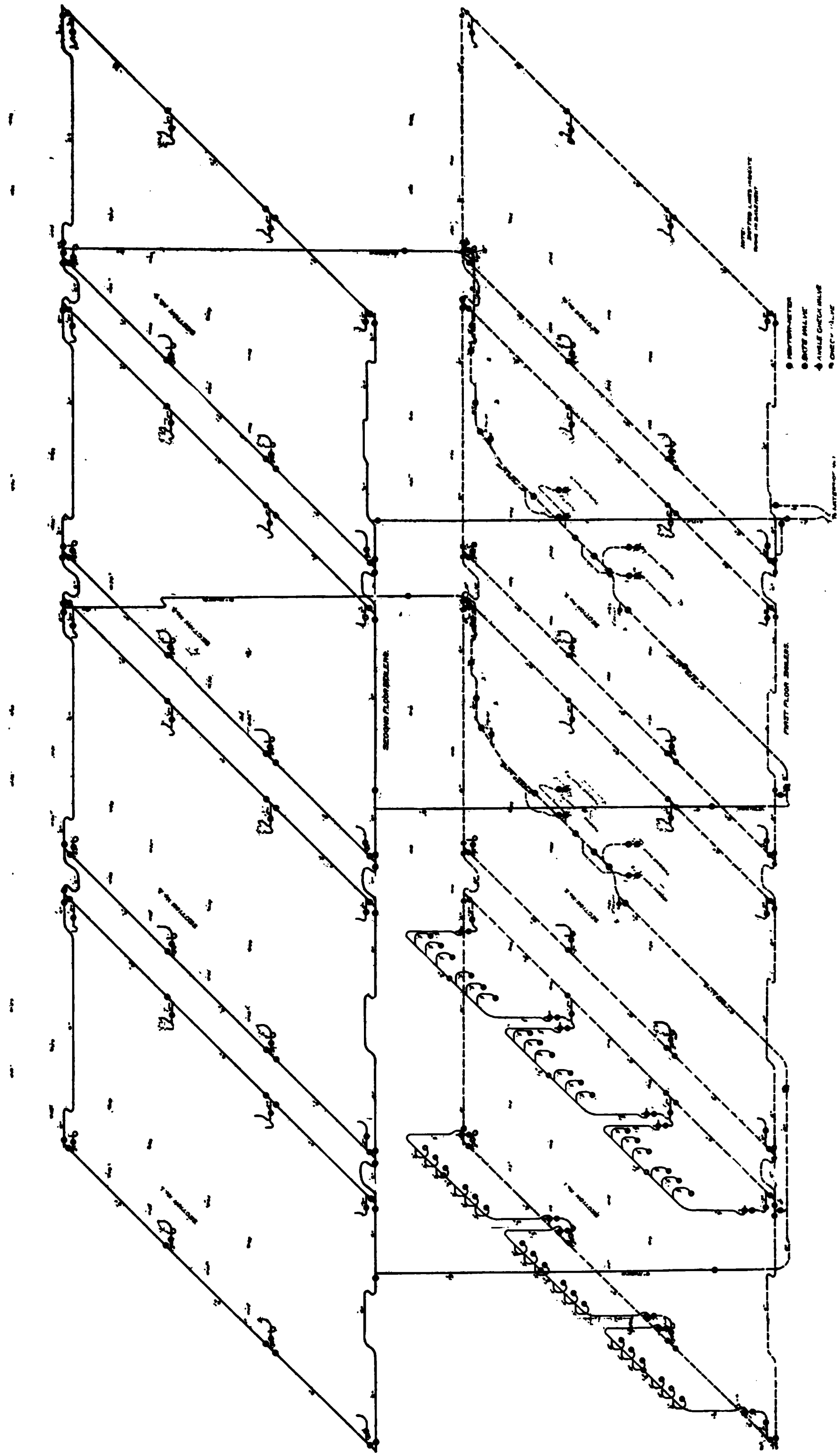


FIG. 27.—Feed Water Piping from Pumps to Mains and Boilers, Waterside No. 2.

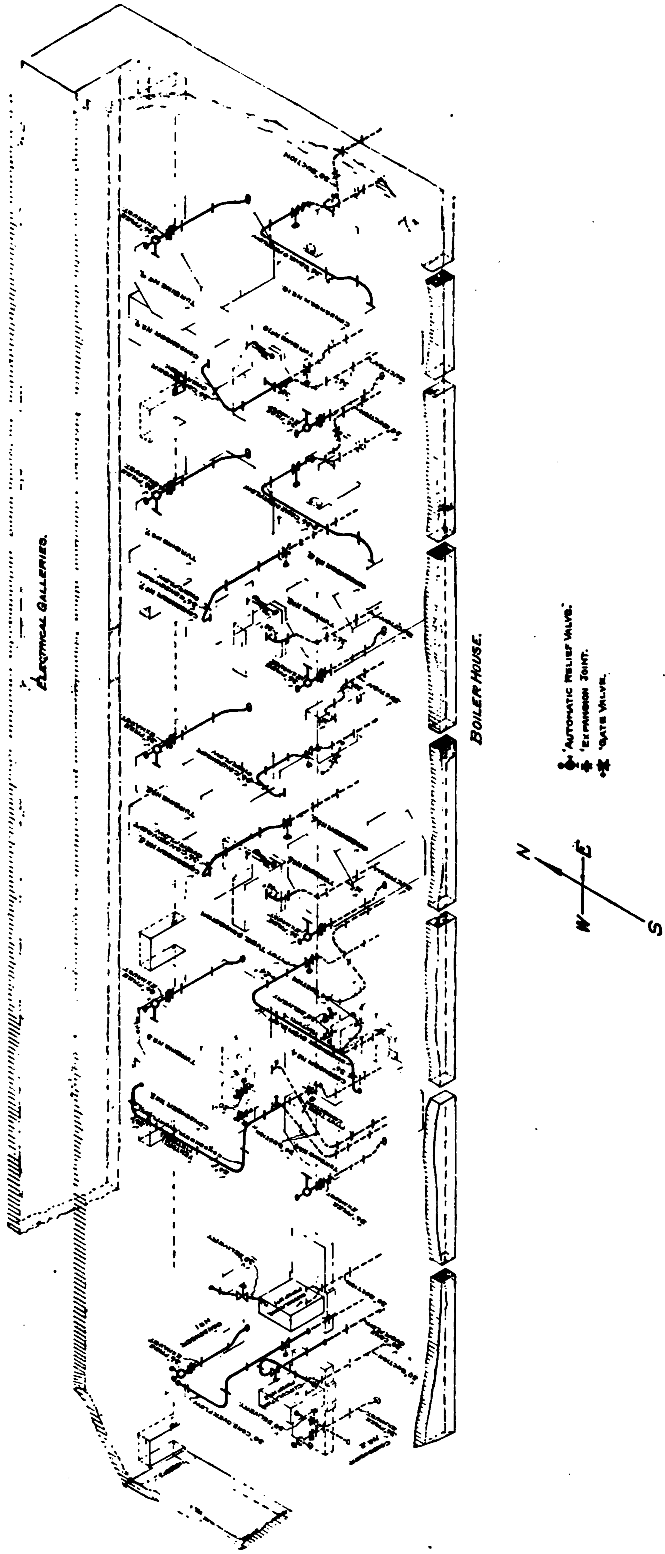


FIG. 28.—Circulating Water System and Free Exhaust, Waterside No. 2.

contains, besides two heaters, four of these five-stage pumps. The heaters are cast-iron, horizontal open heaters, the total cubical contents of each heater being about 1000 cu. ft., and the cubical contents of the storage chamber being 587 cu. ft. Each heater is equipped with an oil separator and cleaning, settling, or sediment trays.

The heaters discharge into a 16-in. suction tie-line, to which the 8-in. suction lines of the feed pumps are connected. The system is interconnected in such a manner that one heater in either pump room may be operated at a time, or both used in multiple.

The feed pumps, four to each pump room, are five-stage centrifugal pumps. Each pump has an 8-in. single suction and 8-in. discharge. They are rated at 1000 gal. per min. when operating against a total head of 700 ft., or approximately 300 lb. pressure at a speed of 1650 rev. per min. To maintain automatically a constant discharge pressure, with varying quantities of water, a pressure regulator is inserted in the delivery pipe to operate in conjunction with and to be a part of the turbine governor. The bearings on the pump are of the self-oiling, ring type, ball-seated, split and removable.

Each pump is driven through a direct, flexible coupling by a steam turbine. The latter are of the single-wheel type, 3 ft. in diameter, 300 brake hp. at 1650 rev. per min. when supplied and steam at 175 lb. pressure and 100 deg. superheat at the throttle. They are governed by fly-ball governors mounted on the turbine shaft. The turbo-pumps were installed because of their low operating cost, the small amount of attendance required and their economy of floor space.

The exhaust steam from the auxiliaries used throughout the station enters the heaters through a 15 by 24-in. elliptical opening. The vapor from the heaters then discharges into a 16-in. vapor-line and thence to the free discharge stack.

The pumps discharge into 6-in. cast-iron feed water ring headers on each tier of boilers through 8-in. risers on the north and south boiler room walls, two risers for pump room No. 1 and two for pump room No. 2. Tie-lines are provided between this station and Waterside No. 1 for breakdown contingencies in either station. Venturi meters, located in the pump rooms, meas-

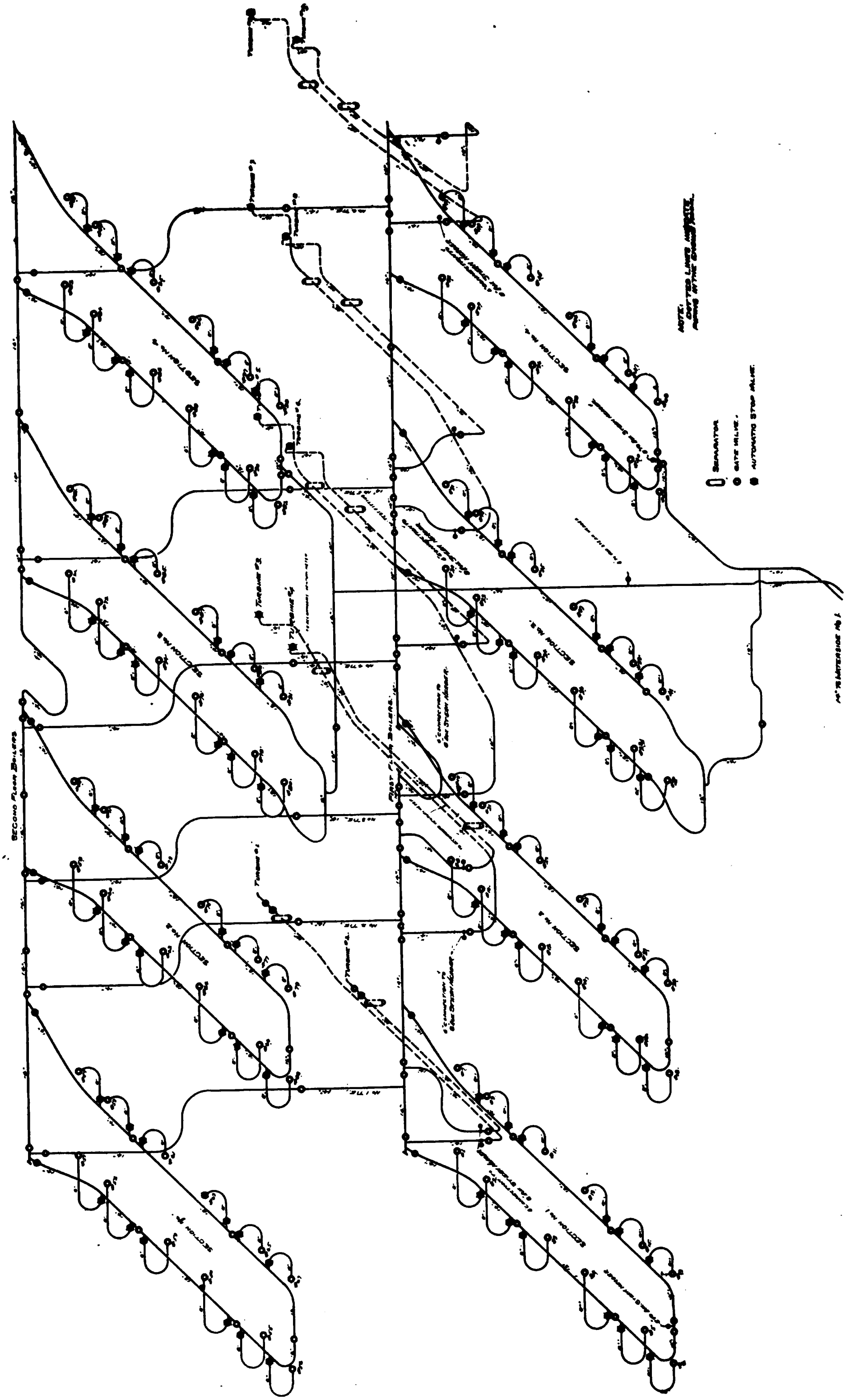


FIG. 29.—Main Steam Piping, Waterside No. 2.

ure the discharge of each pump and a relief valve in the discharge header provides against excess pressure in the discharge, due to throttling the feed valves of the boilers, during periods of light load.

Each section of six boilers is served by a 6-in. tie-line between the headers, and a 3-in. loop, gate valves, angle, swing check, valves, and 2-in. brass branch pipes leading into the drum of each boiler.

THE STEAM PIPING SYSTEM.

Steam from the boilers is taken through sickle bends to loop headers in each section and thence to two 14-in. main steam headers, located in the boiler room, near the division wall, one below the second floor and one below the third floor, each provided with expansion bends. These headers are tied together by six 14-in. vertical tie-lines. The headers and tie-lines, as well as the loops, have valves so located as to permit cutting out any section in case of accident. From the lower 14-in. header the turbine leads run to each of the turbo-generator units in the main engine room.

Each main steam header is supplied by eight boiler room headers, made up of 10, 12 and 14-in. pipe, four feeding the upper main steam header and four the lower one.

Each of the above headers forms a loop over one section of boilers in each tier and is separated into sections by valves between each pair of boilers. Eight-inch U-bends connect these boiler section headers to the manifold on each boiler. In these U-bends a combination stop and check valve is located, the construction of these valves being such that they will automatically close when the pressure of the boilers, to which they are attached, falls below that in the line.

All the high pressure main steam and auxiliary piping is full weight steel pipe; all flanges are Edison, roll-joint pattern; all fittings are open hearth, cast-steel, Edison standard, and all valves are extra heavy steel-seated gate valves.

Adequate superheater and boiler blow-off piping is provided for each boiler, which connects to an 8-in. header in the basement, that in turn discharges into the blow-off tank adjoining the exhaust stack in the northeast corner of the boiler house basement. The discharge from the blow-off tank is metered.

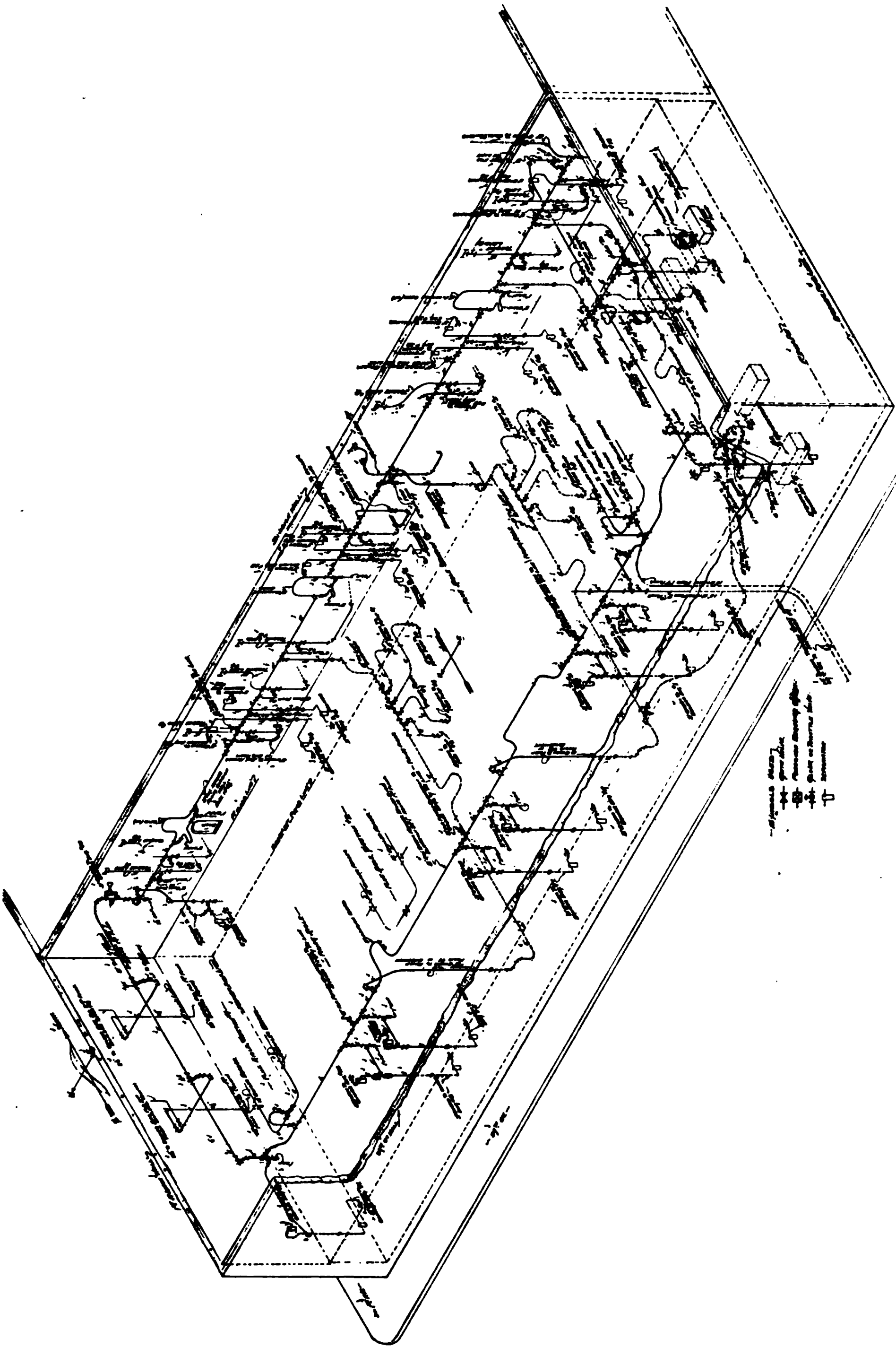


Fig. 30.—Eight-inch Auxiliary Steam Header, Boiler House, Waterside No. 2.

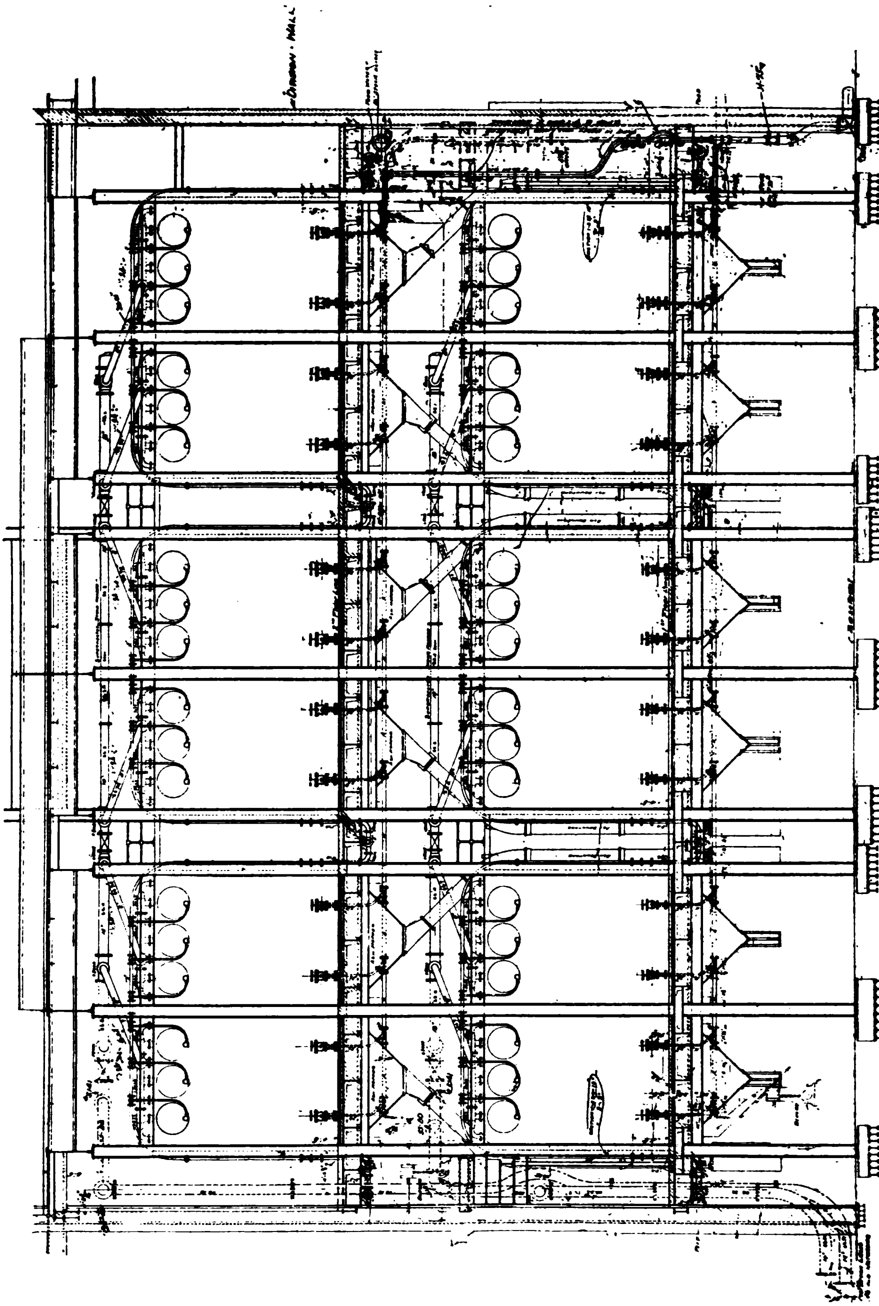


Fig. 31.—Section through Firing Aisle, Boiler House, Waterside No. 2.

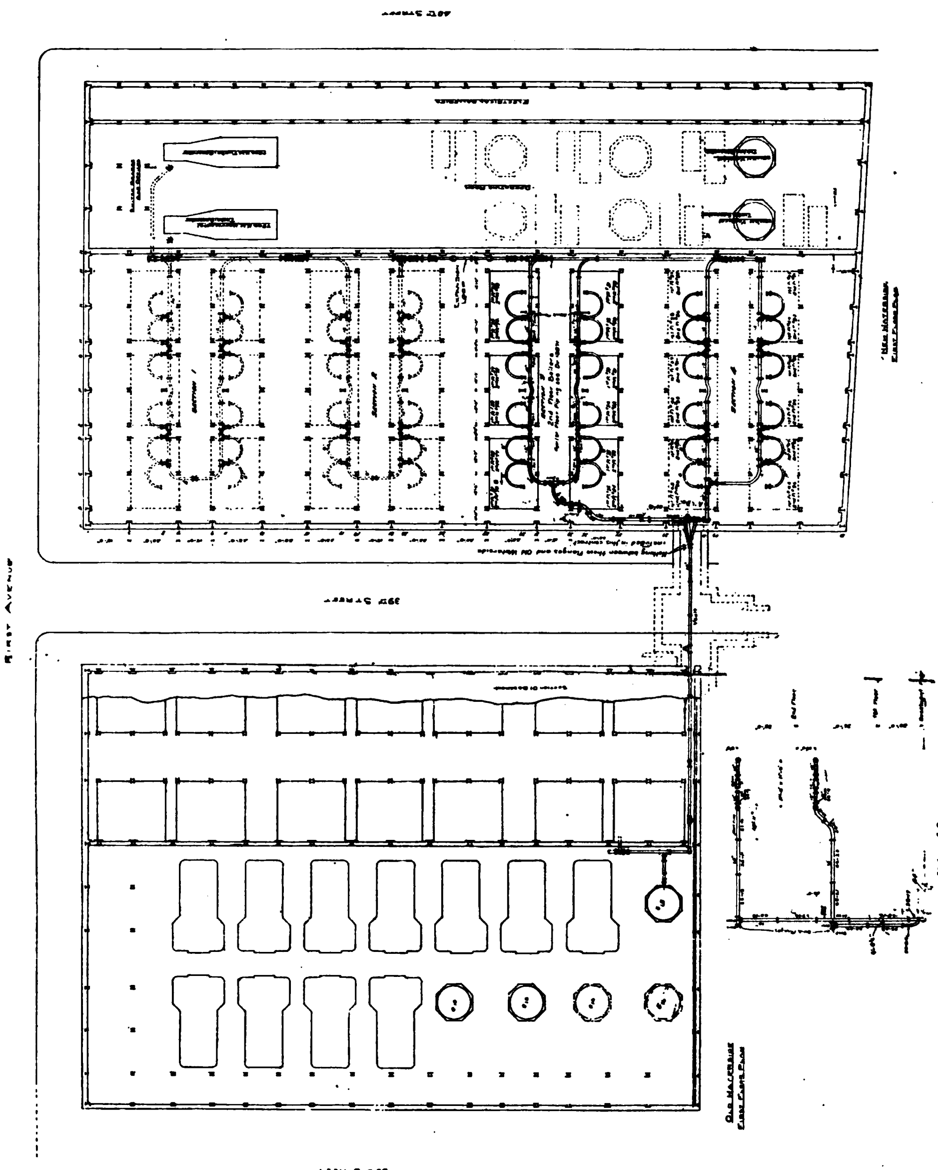


FIG. 32.—Steam Piping Between New Boilers and Waterside No. 1, Waterside No. 2.

There are three drip systems for the high pressure piping:

1. A gravity drip system on all main steam headers and boiler room steam headers that are located above the water-line of the boilers where a gravity return system could be used to advantage.

2. A receiver-pump drip system on all main and auxiliary steam lines in the operating room basement and on the high pressure drip-header on the north wall of the boiler house basement, all of these lines being below the water-line of the boilers, the pump being automatically controlled by a float in the drip-receiver.

3. A drip system to steam-traps, taking care of high pressure drips from the coal tower and the heating system of the building.

In addition to the above a low pressure system is in service for handling the drips from cylinder cocks on all auxiliaries, pumps, blower engines and stoker-drive engines, this system having a free overboard discharge.

FIRE SERVICE.

Water for the fire service and ash-wetting system is taken from the circulating water-intake tunnel. A 12-in. suction pipe from the intake tunnel, branching off into three 8-in. pipes, supplies three centrifugal fire pumps, driven by steam turbines, located in the southeastern corner of the boiler house basement. These pumps discharge into 6-in. ring-header in the boiler house basement, from which all lines for the ash-wetting system and all other fire lines are taken. The service is always in operation.

AUXILIARY STEAM AND EXHAUST SYSTEM.

There is also an auxiliary steam and exhaust system, the auxiliary exhaust header being made up of 8, 14 and 24-in. pipe. It leads into the exhaust flue at the east end of the building through a 24-in. exhaust relief valve. Suitable corrugated copper expansion joints are inserted in the line. At the pump rooms, Nos. 1 and 2, two 24-in. branch pipes are led off, which supply steam to each of the open heaters. A 12-in. vent pipe connects the opposite ends of the heaters directly with the exhaust flue, or stack. Into this exhaust header are collected all the exhaust lines from the auxiliaries and step-bearing pumps in the operating

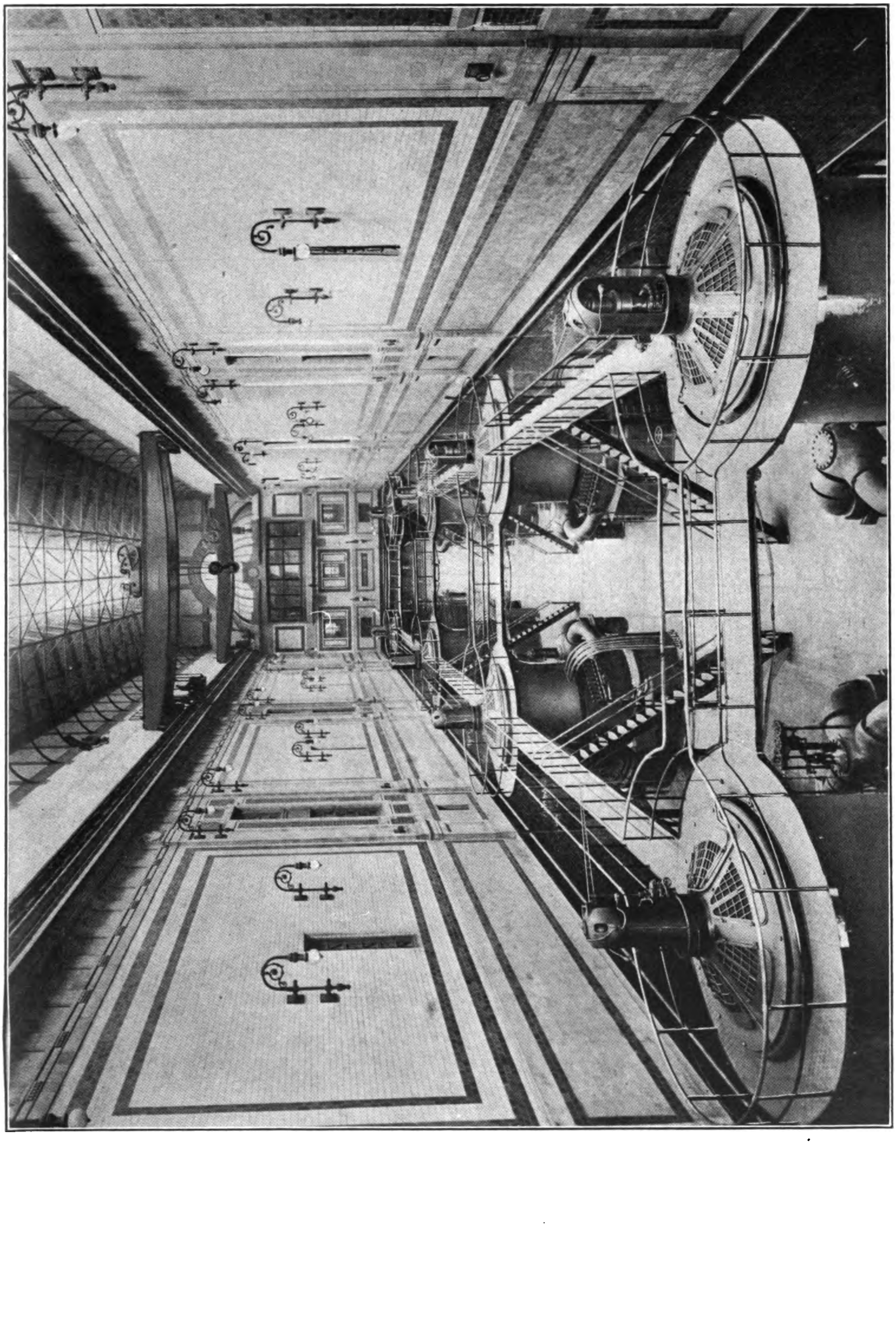


FIG. 33.—Operating Room, Waterside No. 2.

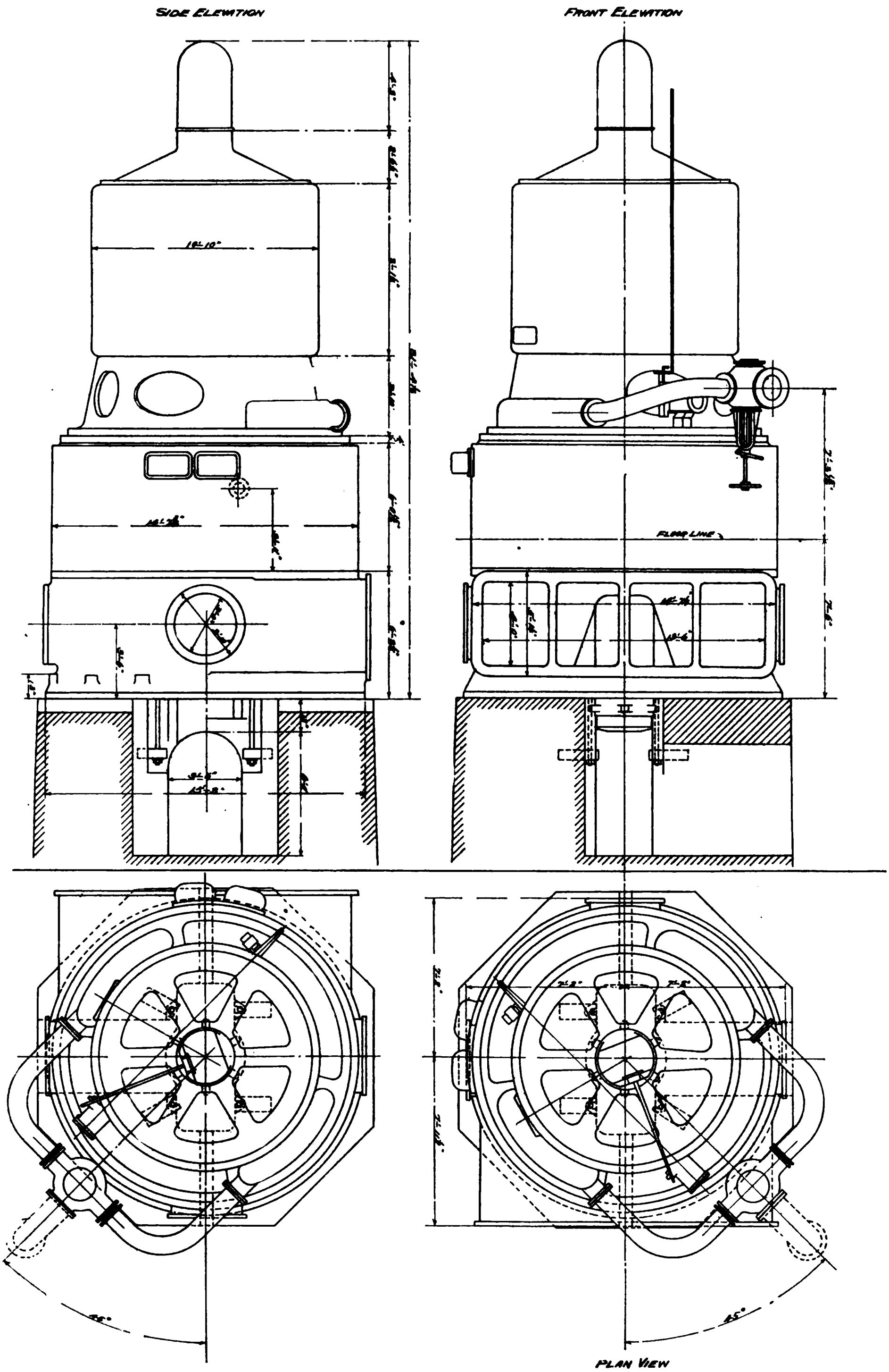


FIG. 34.—8,000-kw. Turbo-Generator Set, General Electric Co., Waterside No. 2.

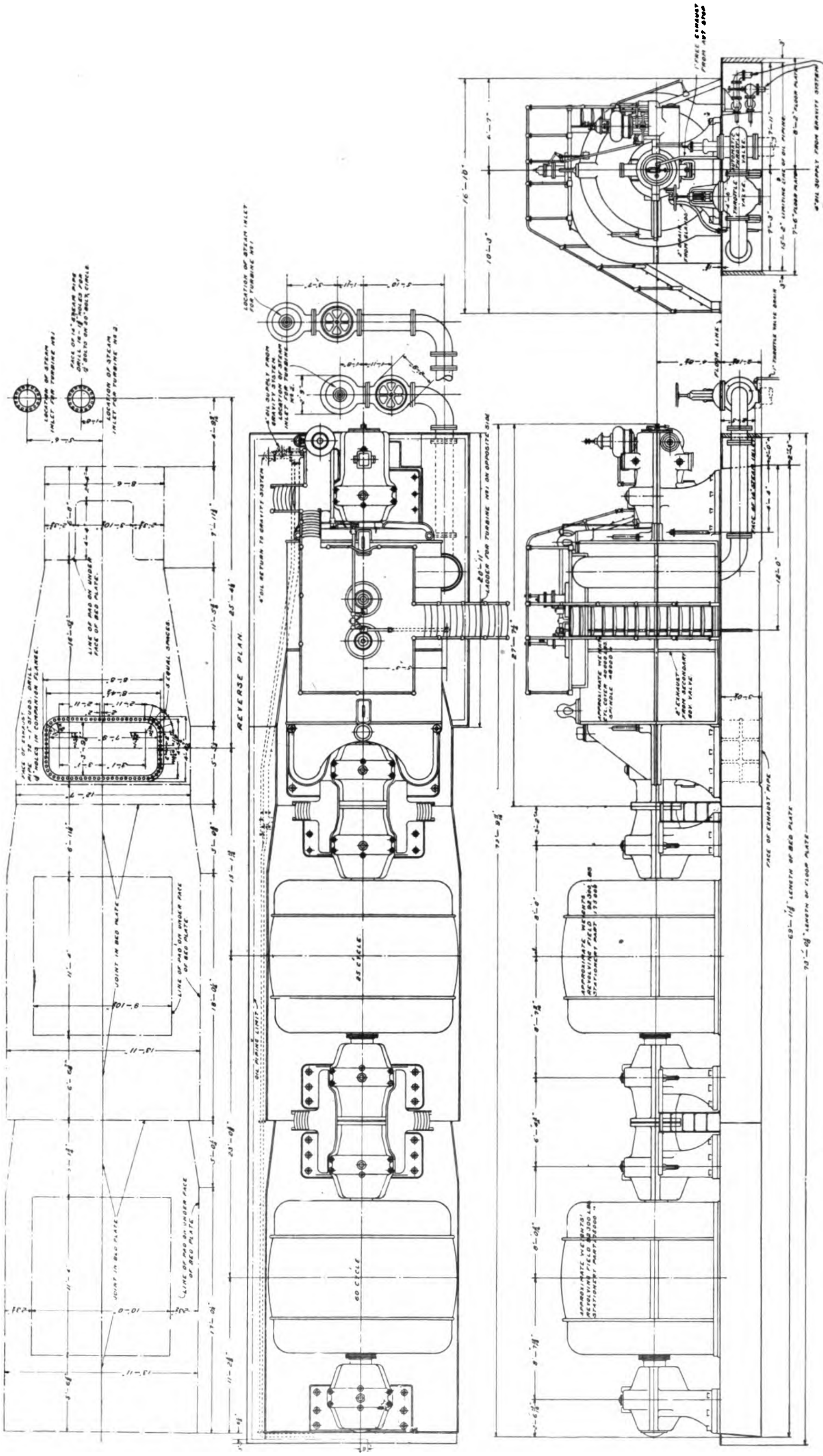


FIG. 35.—7,000-kw. Turbo-Generator Set, Westinghouse Machine Co., Waterside No. 2.

room basement, and all pumps, blower engines, stoker-drive engines, and air compressors in the boiler house.

Provision is made for operating the auxiliaries, either condensing or non-condensing, and a connection with the exhaust header in the boiler house basement through an 8-in. relief valve gives free passage to the atmosphere or to the open heaters. Each set of auxiliaries in the engine room basement receives its steam through a special 6-in. back outlet connection in one of the 14-in. cast-steel ells in the main steam supply to the turbines. In the filter room a 3-in. connection is taken to the oil pumps from the auxiliary steam line of Nos. 1 and 2 turbines as well as a connection made with the boiler room steam ring-header.

All steam lines to the turbines or auxiliaries are provided with steam separators inserted in the line near the prime mover.

COMPRESSED AIR SYSTEM.

Compressed air is used in this station for cleaning the apparatus in both the engine room and boiler house, for pneumatic tools and for blacksmith forges.

The compressor plant is situated, together with the fire pump, in the northeast corner of the boiler house basement. The compressor is a compound 14 and 22 by 16-in. stroke. A 4-in. line from the compressor runs into a 5-in. line, which connects two 24-in. by 12-ft. 4-in. receivers. From the receivers a 5-in. line connects to a 5-in. header, running along the north wall in the boiler room basement, and from this header two 2-in. lines connect with a 2-in. header running along the north wall of the engine room basement. At the point where the 5-in. line leaves the receiver a 4-in. line is run over to Waterside No. 1.

This plant is duplicated in the southeast corner of the boiler house basement.

THE TURBO-GENERATORS AND AUXILIARIES.

The engine room is 57 ft. 6 in. wide, center to center of columns, by 306 ft. long; 28 ft. 9½ in. from the center line of the columns in the south division wall runs the center line of the intake tunnel. The center lines of the horizontal turbo-generators Nos. 1 and 2 lie 16 ft. on either side of this line. The center lines of the vertical turbo-generators are 14 ft. either side of the center line of the intake tunnel. The vertical turbines are spaced 55 ft. center to center, and the distance between the center line of the two nearest vertical turbines and the center lines of the 25-cycle horizontal generators is 55 ft.

Turbines Nos. 1 and 2 drive two generators of 7500-kw capacity each, one 25-cycle and one 60-cycle. All the other units are 8000-kw. vertical turbines, excepting Nos. 3 and 4, which are 14,000 kw.

Condensing water for all the units is taken from the in-take tunnel and is discharged into the two overflow tunnels, located on either side of the intake, but at a higher level.

The high pressure steam mains to the turbines are supported from the steel frame of the operating room floor, passing up through holes in the floor to the turbines. The high tension cables from the generator pass out to the switches in the electrical galleries on the north, through vitrified ducts laid in concrete, suspended from the operating room floor. The generator armatures are air-cooled through ventilating ducts and blowers on the generator shaft.

Turbo-units, designated as Nos. 1 and 2, are of the horizontal multiple expansion type, connected to twin generators, running at 750 rev. per min. Steam is admitted from the 14-in. turbine lead through a separator, automatic valve, throttle valve and strainer to the inlet on the turbine. The exhaust area to the condenser is about 29 sq. ft. Free exhaust to the exhaust stack is through a 30-in. pipe to the exhaust tunnels and thence to the stack. The generators, of which there are two, direct connected to the turbine, are 25 and 60 cycles, respectively. The 25-cycle generator is of the revolving field type, three-phase, 7500 kw., 4-pole, 6600 volts, and runs at 750 rev. per min. The 60-cycle generator is a three-phase, 7500-kw, 10-pole, 6750/9250-volt revolving field generator.

The turbines are governed by a balanced poppet valve controlled by a flyball governor. Each turbine is also provided with a secondary governor valve, by means of which 50 per cent overload may be developed, or full load developed when operating non-condensing. This valve is automatically operated by a mechanism in connection with the main governor and is arranged

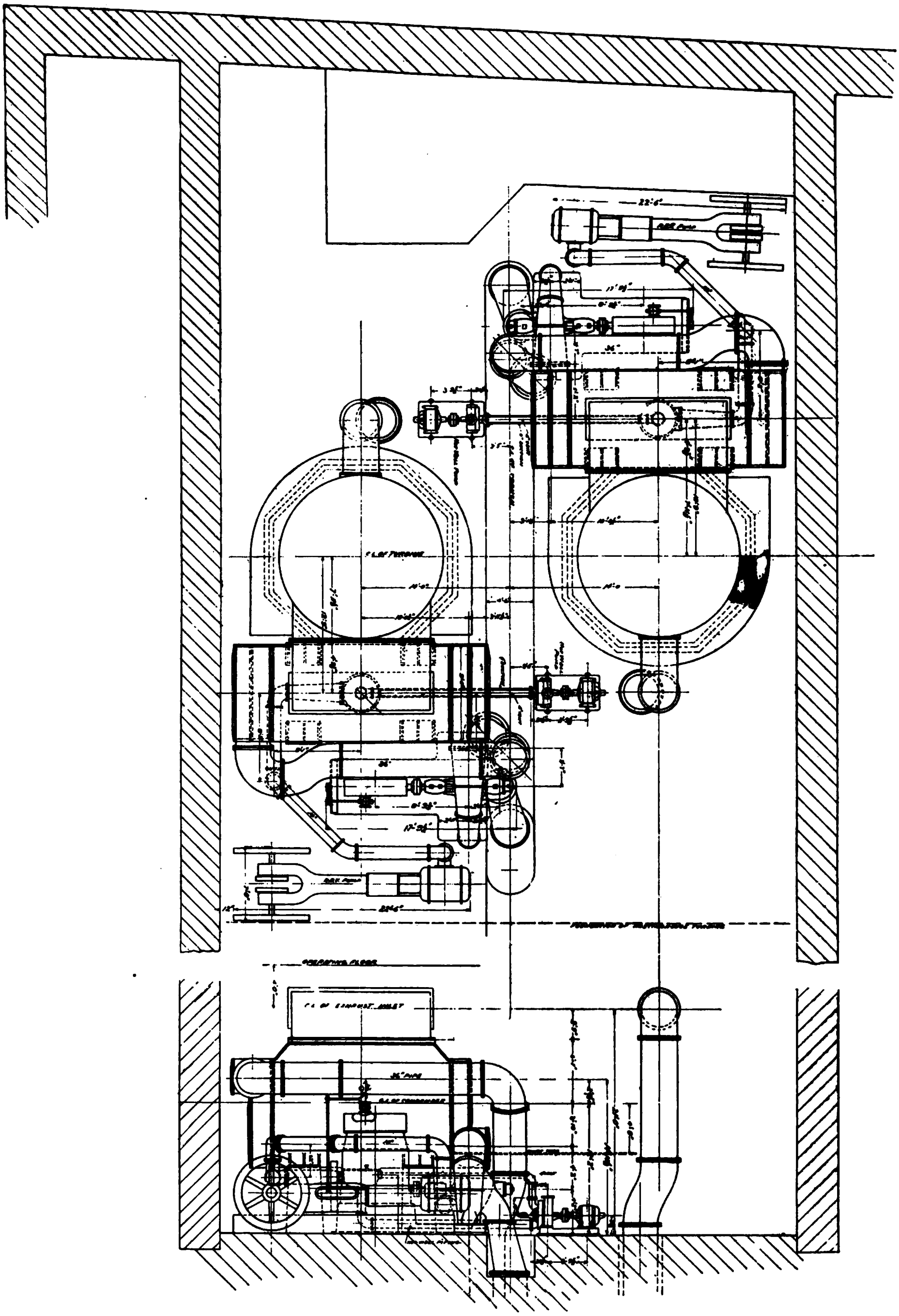


FIG. 36.—Worthington Condensers, Waterside No. 2.

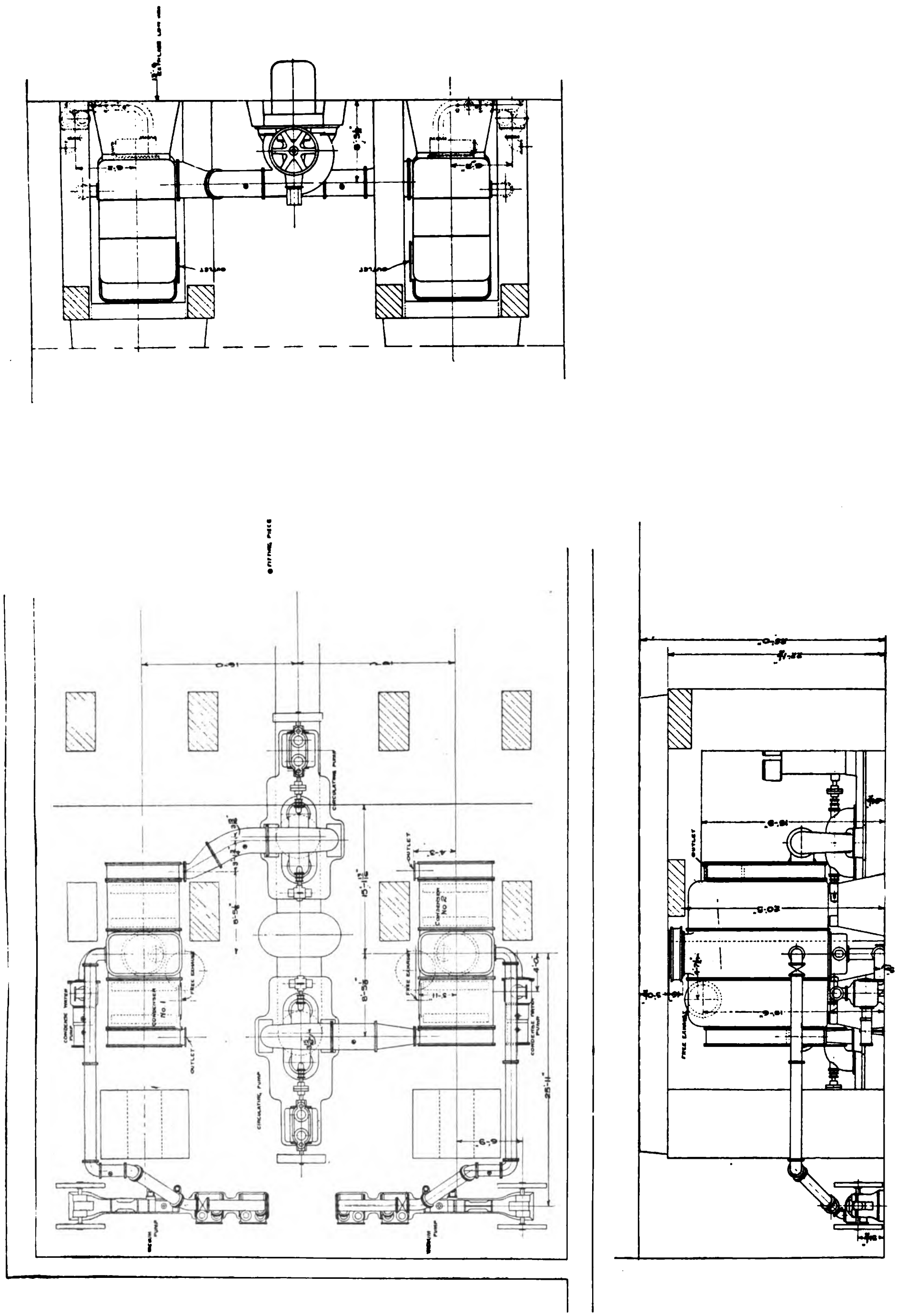


FIG. 37.—Alberger Condensers, Waterside No. 2.

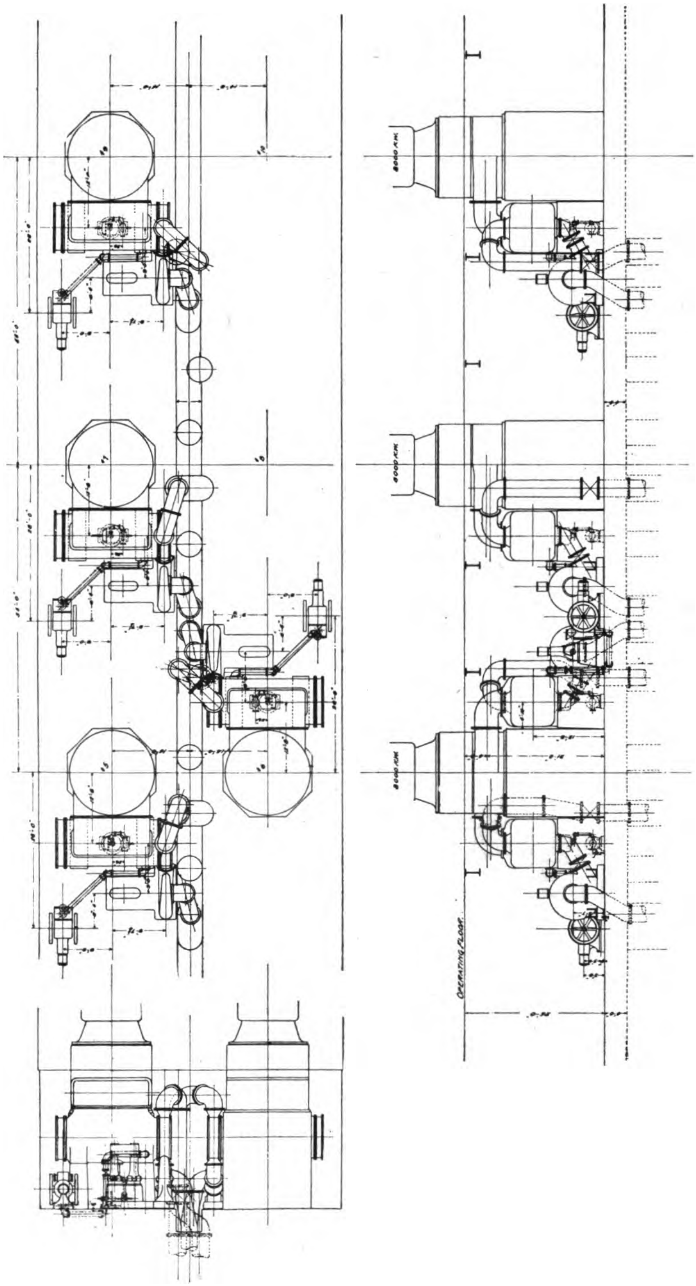


FIG. 38.—Wheeler Condensers, Waterside No. 2.

to open whenever the load exceeds the amount that the turbine can carry normally. It will also operate, should the vacuum or steam pressure fall to a point where the turbine is unable to carry the load, and will automatically return to its seat when the overload falls. In addition, provision is made for operating the governor for synchronizing from the switchboard. A quick operating throttle-valve, in combination with the auxiliary governor, automatically closes if the turbine speed exceeds the safe limit.

The turbine set complete is 50 ft. over all and weighs 900,000 lb.

The foundation for these turbo-generators consists of a platform constructed of 12-in. I-beams imbedded in concrete and supported on six concrete piers, reinforced by ¾-in. iron rods. There is also a seventh pier supporting the admission end of the turbines. The foundations for these two turbines are also tied together at three points with 15-in. I-beams imbedded in concrete.

The condensers are three-pass surface condensers with 25,000 sq. ft. of cooling surface, and have the following overall dimensions: 8 ft. 2 in. wide, 19 ft. 5½ in. long, 14 ft. 11 in. high, from bottom of legs to face of exhaust inlet.

Each condenser was specified to be able to maintain a 28-in. vacuum, referred to a 30-in. barometer when condensing 180,000 lb. of steam per hour, and when supplied with condensing water of a temperature not exceeding 70 deg. fahr., and, furthermore, each condenser must be able to maintain a 27½-in. vacuum under the above conditions when condensing 220,000 lb. of steam per hour.

Circulating water enters at the bottom through an opening 3 ft. 6 in. by 17 in. and leaves at the top of the condenser through an opening of the same size. Each condenser is located directly under its turbine between the support piers and is connected to the exhaust nozzle of the turbine by a special expansion joint.

A 12-in. dry air suction connects the condenser to the dry vacuum pump, which is a single-stage tandem, 10 by 24-in. and 24 by 24-in. Corliss-driven pump, rated at 85 rev. per min.

The condensate flows or drips down into an automatic hot well which is a closed cast-iron chamber attached to the bottom of the condenser. This hot well contains an open float, counterbalanced by a spiral spring, the motion of the float being communicated to the prime mover control of the hot well pump. The hot well pumps are direct acting monitor.

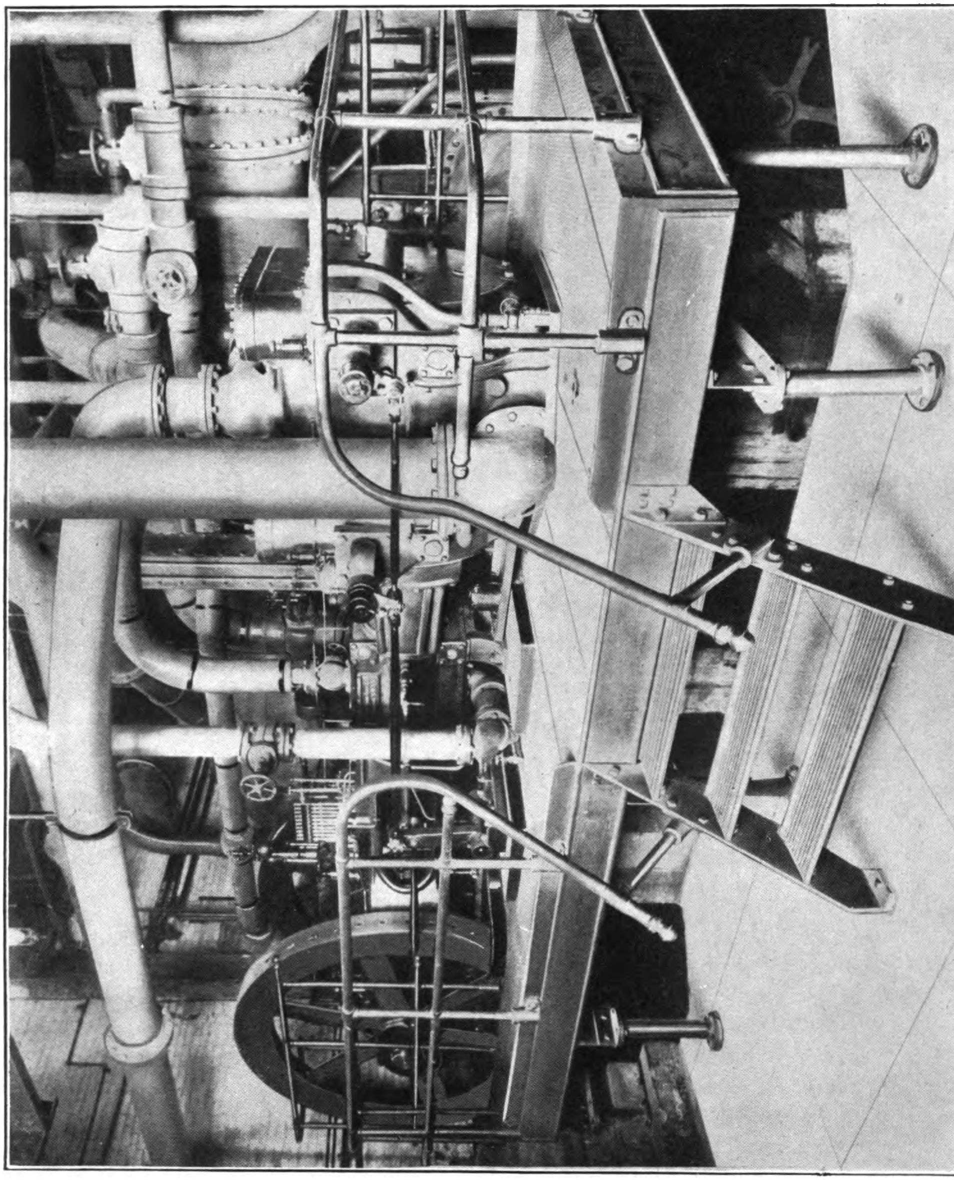


FIG. 39.—Condenser Auxiliaries, Waterside No. 2.

Circulating water is obtained from the in-take tunnel by means of double suction centrifugal pumps direct-connected to 12 by 12-in. vertical steam engines.

Turbines Nos. 5, 6, 7, 8, 9 and 10 are vertical five-stage turbines of 8000 kw. capacity, 750 rev. per min., direct-connected to 4-pole, 25-cycle, 6600-volt, three-phase generators with revolving fields. These machines are capable of carrying an overload of 4000 kw., above rating, or 12,000 kw., the turbine to regulate within 2 per cent from no load to full load with a permissable momentary variation of 4 per cent. The turbines have the standard, mechanical, hydraulic, admission valve control. Steam is admitted to the turbine through a 14-in. lead, through a strainer to the admission valve casting.

The condensing apparatus for turbines Nos. 5, 6, 7 and 9 are similar in general arrangement to Nos. 1 and 2, as regards auxiliaries, but they differ in the cooling surface and one or two other details. The condensers for these turbines are set on a separate foundation alongside the turbine foundation, connected to the turbine sub-base by an exhaust elbow.

These condensers are of the 2-pass surface type and contain 18,000 sq. ft. of cooling surface. The exhaust opening is 13 ft. 6 in. by 4 ft., or 54 sq. ft. The circulating water inlet at the bottom of the condenser is 30 in. in diameter and 36 in. at the top.

The circulating water pumps are 30-in., volute, centrifugals direct-connected to double 11 by 12-in. vertical engines.

The condensate from the condensers is received in automatic hot-wells, which are connected to horizontal volute type, single-stage, centrifugal turbine-driven pumps, having a capacity of 500 gal. per min., against a total discharge head of 55 ft. when the vacuum is 28 in. and when running at 1500 rev. per min.

The dry vacuum pumps are 11 by 30 by 14 in., double-acting steam pumps, with water jacketed air-cylinder, which run at 70 rev. per min. The air inlet is 10 in. and the outlet 8 in., connecting directly with the condenser and vapor line respectively.

The condensers for turbines Nos. 8 and 10 are 3-pass surface condensers, containing 23,700 sq. ft. of cooling surface. The remainder of the auxiliary apparatus is similar to the other condensers, excepting the dry vacuum pump, which is a single, horizontal, tandem, Corliss gear, 13 by 32 by 24-in. pump, running at 86 rev. per min.

All the above condensers have the same specifications regarding vacuum as those for the horizontal turbine condensers already described.

Turbines Nos. 3 and 4 are 14,000 kw. vertical turbines, coupled to 60-cycle and 25-cycle generators, respectively, with no overload allowance. The turbines are 5-stage, 750-rev. per min. machines, with the same mechanical characteristics as the other units.

The condenser is a dry tube surface condenser, containing 18,000 sq. ft. of cooling surface.

The circulating water apparatus consists of two double-suction horizontal shaft centrifugal pumps, direct-connected to two 8-stage steam turbines of 200 b.hp. at 750 rev. per min. The pump suction is 24 in. and the delivery is 20 in. in diameter. The dry vacuum pump is a direct acting fly-wheel pump.

The wet vacuum, or hot well pump, is a 12 by 20 by 24-in. direct-acting pump with 10-in. suction and discharge connected to the automatic hot well.

THE INTAKE, OVERFLOW AND EXHAUST TUNNELS.

Salt water for condensing purposes is brought into the building and distributed to the suctions of the circulating pumps through a concrete intake tunnel. This tunnel extends to within some 22 ft. of the west end of the building, along the center line of the operating room. It has a cross sectional area of approximately 118 sq. ft. Circular openings 4 ft. 6 in. in diameter are provided for the suction pipes of the various circulating pumps, the top of the tunnel being some 16 ft. below the basement floor line.

At a higher elevation and 5 ft. on either side of the center line of the above tunnel are the overflow tunnels, each having an area of about 50 sq. ft. Openings are again provided in the floor for each of these tunnels to admit the overflow pipes from the condensers. Both of these overflow tunnels unite at the east end of the building into one large tunnel of an area equal to the in-take tunnel and extending out to the river. (See cross section.)

Outside of the overflow tunnels, and paralleling them, have been constructed the two free exhaust tunnels that conduct the vapor of the atmospheric exhaust of the turbines to the exhaust flue or stack at the northeast corner of the boiler house. Each of these tunnels has a sectional area of 30 sq. ft.

All tunnels have been constructed in a solid concrete monolith lying along the center and below the operating room basement, the walls of which are about 2 ft. thick. Electrically operated, vertical, centrifugal, sump pumps are installed, one in the north tunnel and one in the south in order to take care of the seepage. The exhaust tunnels are lined with sectional cast-iron plates, bolted together and grouped in place.

SCREEN WELL.

A screen well is provided in the in-take tunnel, just outside the building, 22 ft. wide by 12 ft. 6 in. long. The well itself is 29 ft. 2½ in. deep. The walls are of reinforced concrete, ranging in thickness from 3 ft. at the bottom to 2 ft. at the top.

The screens consist of heavy gratings and fine screens so arranged as completely to cover the intake tunnels. The gratings are made in four frames, weighing about 6000 lb. each. They are removable and are supported on 8 by 16-in. yellow pine timbers. There are three fine screens to a frame, eight of these frames in four parallel guides and so arranged as to be removable by the screen hoist, which is a 5-hp. electric hoist with tackle. The place of any pair of screens may be taken by the spare screens sliding in parallel guides in the rear.

The screen well, platform and hoisting gear are protected by a substantial brick and granite faced house of the same general architectural design as the main building and of sufficient height to permit of the ready removal of the screens.

THE OIL SYSTEM.

Cylinder and engine oil is received in the oil vault under the Fortieth Street sidewalk, where separate steel tanks are provided for the various kinds of oil. A 5-in. line conducts the engine oil to the suction supply of four oil pumps, located in the filter room at the west end of the engine room basement. From this point it is pumped to the two tanks located in the roof house. This is accomplished by means of either of two 5-in. risers connected to the discharge of the pumps and leading to the roof tanks through a brick-enclosed pipe shaft and passageway. Similarly two 5-in. pipes conduct the returns of the system. This provides a positive head of from 40 to 50 lb. throughout the system, which

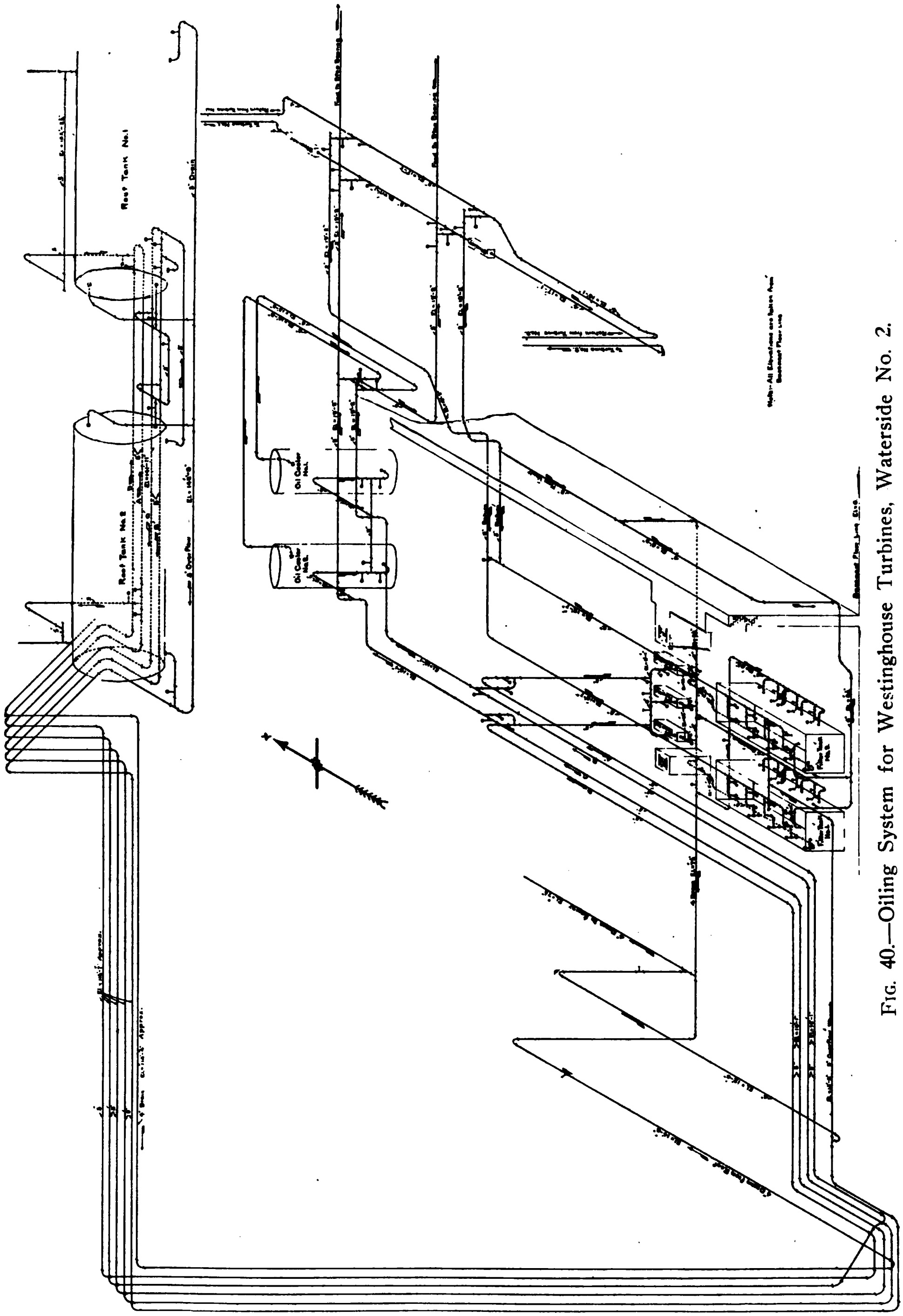


FIG. 40.—Oiling System for Westinghouse Turbines, Waterside No. 2.

is also utilized for the operation of the hydraulic governors on the vertical turbines. Suitable cross connections in the filter room enable the operator to cut out the roof tanks and to pump directly into the system, should occasion require. To prevent the possibility of over-filling the roof tank, a 5-in. overflow pipe runs to the filter tanks below. A 4-in. line drains the floor of the roof house into the oil sump under the floor of the filter room.

For cylinder oil, the two separate cylinder oil tanks in the receiving vault are connected with the cylinder oil pumps in the filter room by two 2½-in. pipes. The discharge is through two 2-in. pipes, connecting with the ring-headers, distributing cylinder oil throughout the station. This discharge is also connected by two 2-in. risers to the cylinder oil tanks in the roof house, and is thus provided with a constant head.

The two 5-in. pipes leading down from the engine oil tanks on the roof are continued along the division wall of the engine room basement to the point where taps are taken off to supply the bearings of turbines Nos. 1 and 2. From this point 4-in. mains are continued throughout the length of the station with 2-in. branch pipes at each vertical turbine to supply the vertical bearings and hydraulic governors. Oil is supplied to the bearing system of the vertical turbines by 3-in. branch pipes leading from these mains to the step-bearing tanks located near the north division wall at the base of turbine No. 3 and turbine No. 9.

The step-bearings of the vertical turbines are supported on oil at pressures ranging from 900 to 1500 lb. per sq. in. This pressure is maintained, first, by the steam step-bearing pump located at each turbine and, second, by connection with the 4-in. accumulator line which compensates for any variation in the steam pump service. In practice the pressure of the lines are maintained at 1200 lb., and a pressure of 1000 lb. in the step-bearing baffler. The mean bearing area of the step is 168 sq. in. The 4-in. supply lines, two in number, run along the division wall of the operating room basement and are connected to two accumulators, two steam step-bearing pumps and four emergency electric step-bearing pumps; the suction of these pumps is connected to a 6-in. suction ring-header, running around the perimeter of the engine room basement and supplied with oil from the two step-bearing tanks located near the north division wall.

These tanks are connected by a 6-in. equalizer pipe. Provision is also made for taking oil from the tanks in the filter room, should occasion require. The oil supply is delivered to the step-bearing through a 2-in. pipe, stop-valve, check-valve and baffler. All the piping of this system is double, extra heavy galvanized pipe with hydraulic fittings and special flanges

The returns from the step-bearings are 2½-in. pipes connected to a 6-in. return header leading to the step-bearing tanks, and, in case of emergency, to the filter tanks in the filter room. In these tanks the oil is strained, allowed to separate from any water that may be entrained in it, cooled by water coils, and returned to the step-bearings. On the average the oil per step-bearing per minute amounts to 20 gal. Oil for lubricating the blower engines in the boiler house, and the feed pumps in the basement, is supplied through upper and lower ring-headers, consisting of two 1½-in. pipes, one for engine oil and the other for cylinder oil. Two similar headers in the engine room basement supply oil to the auxiliaries of the turbines. These headers are connected directly to the returns leading down from the oil tanks in the roof house. At present a system of oiling stations has been installed, the oil being piped directly into 5 and 10-gal. tanks convenient to the engines.

THE ELECTRICAL EQUIPMENT.

The three high-tension cables from the armatures of each of the turbo-generators are led through vitrified ducts under the operating floor, as described, to similar ducts in the north division wall leading to the main oil switches, located on the fourth mezzanine floor of the electrical gallaries. On this floor are also located the feeder oil switches. From these switches are run the outgoing, high-tension, triplex feeder cables of the distributing system.

The third mezzanine is devoted to transformer compartments, the second to the selector oil switches and the first to the high-tension main and auxiliary buses. All of these switches are of the remote control type and are operated from the switchboard gallery at the west end of the operating room. The control cables are distributed to the various switches and transformers throughout the galleries through a control pipe run, rising the height of and occupying all of the sixth mezzanine floor.

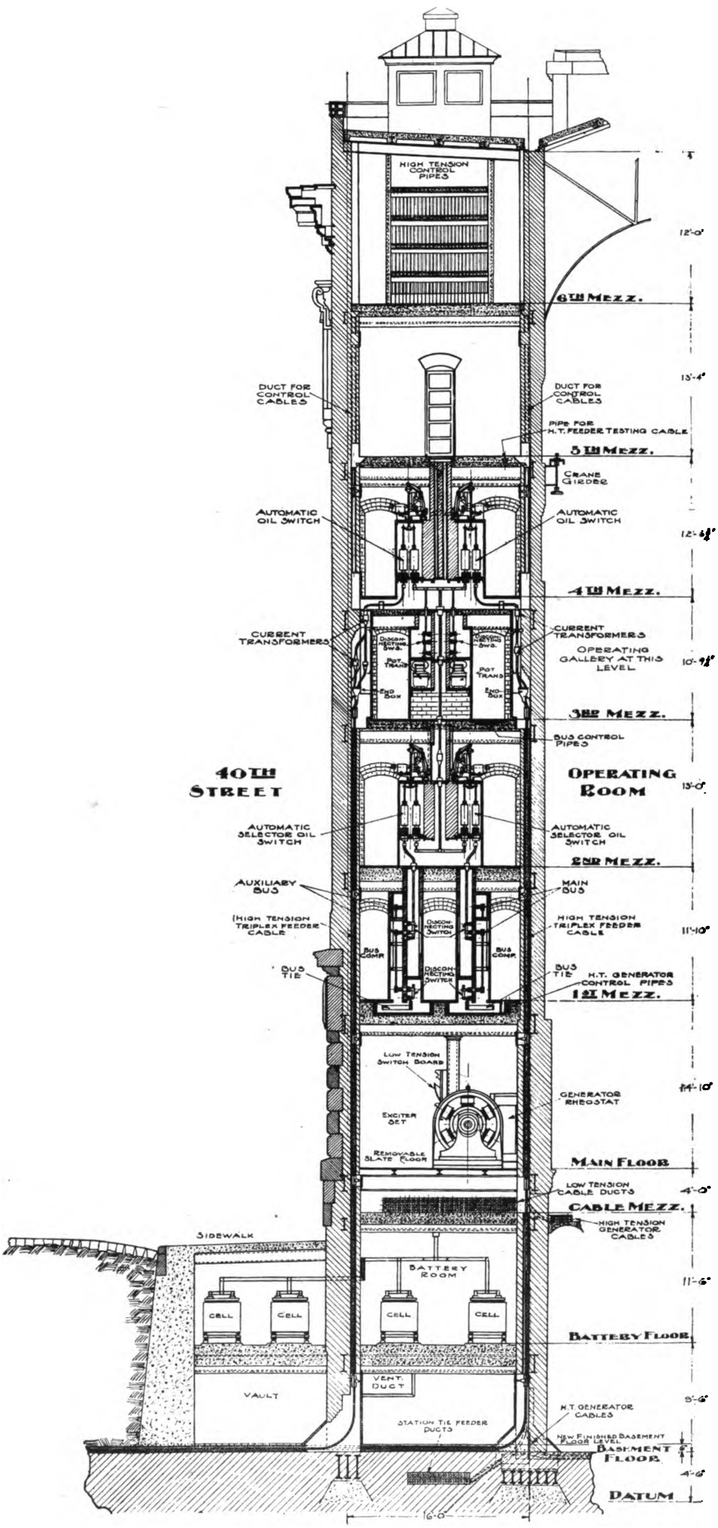


FIG. 41.—Cross Section through Electrical Galleries, Waterside No. 2.

The main generator cables are 1,500,000 cir. mil, single-conductor, cotton-covered, extending from the high-tension buses to the terminal board on the generator. The generator field cables are 400,000 cir. mil, lead-covered. The field ammeter leads are No. 6 duplex, lead-covered. The lead-covered cables, excepting the control cables, are grounded with 250,000-cir. mil cables, bare.

GENERATOR CONTROL.

The generator control consists of 10 control pedestals and instrument panels of blue Vermont marble, mounted on substantial steel frames, forming the arc of a circle. The equipment for each control pedestal and instrument panel comprises the usual instruments, ammeter and shunt, voltmeter, power factor indicator, watt-hour meters and switches; all the instruments have marine finish.

In addition to the panel instruments for generator control, there is installed on the generator instrument panels, an engine signal device, consisting of a metal box, containing signal lamps and illuminated ground glass plates with the words **FULL SPEED, O. K.,** and **SHUT DOWN** in black letters.

The signal stand near the throttle of each turbine contains a signal with illuminating signs as follows:

Stand By	**Start**	**Load off**
Full Speed	**O. K.**	**Shut Down**

and three special knife switches for operating the signals on the generator control-board, one synchronizing lamp and one frequency indicator used as a speed indicator when synchronizing.

The speed of the turbines may be altered when synchronizing by a small motor, operating a worm and split-nut on the governor collar, this motor being controlled from the switchboard.

The field rheostats of the generators are located on the exciter floor and are electrically operated from the control gallery. This control includes an electrically operated field switch with opening and closing magnets and discharge coil, a motor-operated rheostat panel and boxes of grid resistances enclosed in a perforated iron case.

The feeder control board is located in the switchboard gallery and faces the generator control board. It consists of blue Ver-

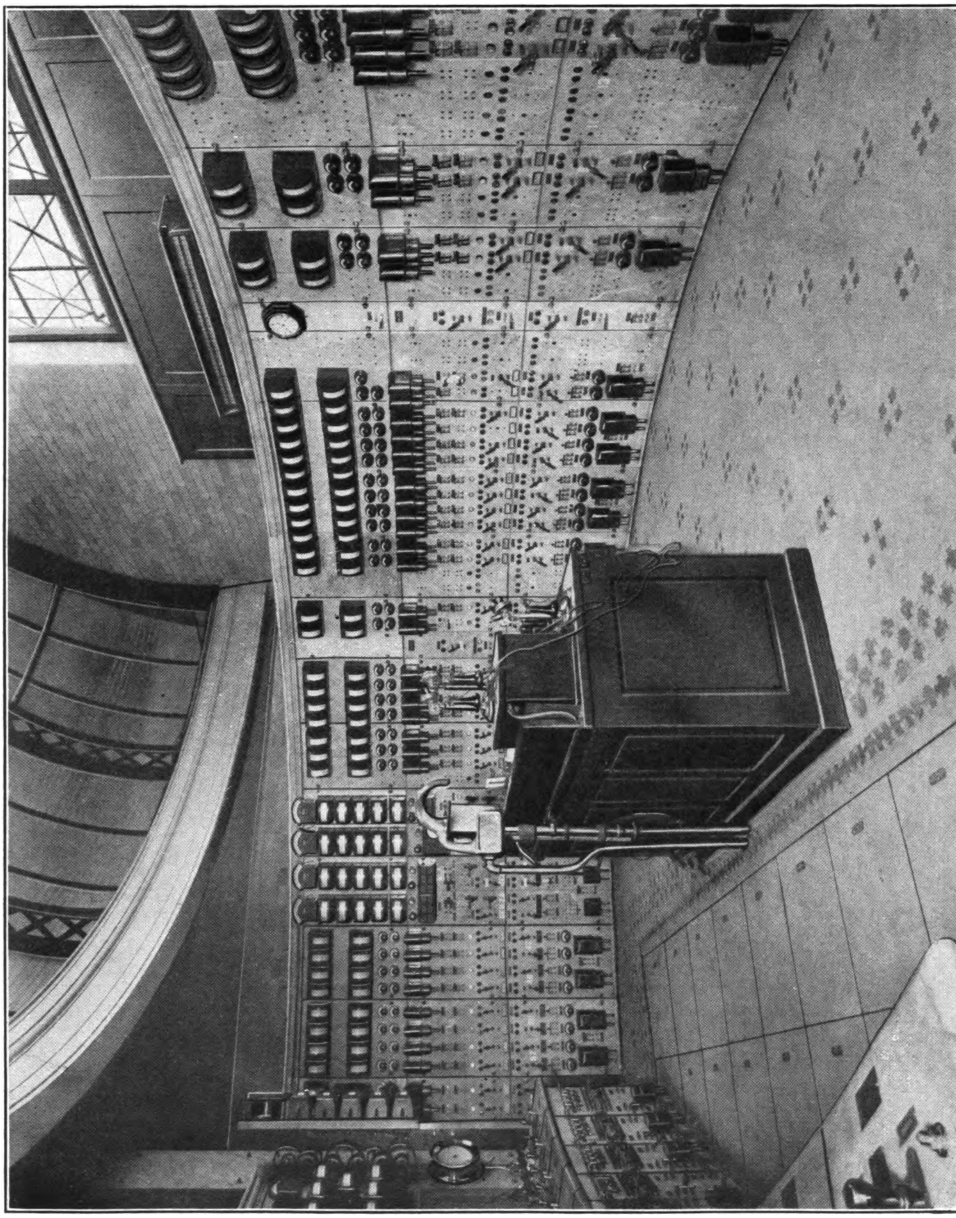


FIG. 42.—Front View of Feeder Control Board, Waterside No. 2.

mont marble panels bolted to a steel frame, conforming closely to the arc of a circle. This board comprises twenty sections, seventeen sections designed for the control of four feeders each and three sections for two feeders each. The 60-cycle feeders occupy two and one-half of the adjacent four-circuit panels and one of the two-circuit panels. Each section, front and back, comprises six panels. The oil switches and transformers for these feeders are located in the electrical mezzanine.

FEEDER CABLES.

Three 500,000-cir. mil cotton braid cables lead from the buses up to the fourth mezzanine where the two feeders branch off. From this junction, three 250,000-cir. mil single-conductor cotton braid cables lead to the high-tension triplex bell on the third mezzanine, then from this point, two 250,000-cir. mil high-tension, triplex, lead covered, cables lead, one to each feeder in each wall.

BUS TIE CONTROL.

The four sections of each bus are tied together by two 1,500,000-cir. mil cables in each phase and the oil switches located in these circuits are controlled by their bus tie sections in the feeder board. Each section of the control-board has six panels supporting instruments. The middle panel takes care of the auxiliary bus tie, the bottom panel the main bus tie. Each of the three sections supports the necessary signal lamps, switches and instruments.

HIGH-TENSION BUSES.

The high-tension buses are made up of 4 by $\frac{1}{8}$-in. copper straps separated from each other $\frac{1}{8}$ in. In the two middle sections the buses are made up of six straps, having a cross section of 3,816,000 cir. mils, the end sections having four straps of 2,544,000 cir. mils.

STATION TIE CONTROL.

The high-tension buses of Waterside No. 2 have been named in the following order from West to East:

$$\frac{\text{60 cy. Main}}{\text{60 `` Aux.}} \quad \frac{\text{W. South Main}}{\text{`` `` Aux.}} \times \frac{\text{E. South Main}}{\text{`` `` Aux.}}$$

$$\times \frac{\text{W. No. Main}}{\text{`` `` Aux.}} \times \frac{\text{E. No. Main}}{\text{`` `` Aux.}}$$

The East North main and auxiliary and the West North main and auxiliary buses are tied in with the corresponding bus of Waterside No. 1. These ties are 1,000,000 cir. mil single-conductor lead-covered cables, and the two 1200-amp. oil switches of each circuit are located in Waterside No. 2. Each station tie is controlled from a separate pedestal in the generator control-board. The arrangement includes the bus instrument panels and the synchroscope panel mounted on a swinging bracket.

FEEDER TESTING SET.

In order to apply a high-pressure breakdown test to outgoing feeders a permanent feeder testing set has been installed in the electrical galleries by which means one of the high-tension 25-cycle feeders is passed through a step-down transformer, the secondary of which is 200 volts. A three-phase induction regulator, hand and motor operated, enables the operator to vary this voltage between 0 and 400 volts while three fixed resistances in circuit limit the current in case of breakdown of feeder insulation. The circuit is further opened through an automatic triple-pole type K switch of 500-amp. capacity, hand operated. The closing of this K switch passes the circuit through a step-up transformer to voltages varying from 7500 to 26,000, according to the connection used. This high-pressure circuit after being broken by three high-tension electrically operated K switches is conveyed to the testing stations on the fourth mezzanine through a special 50,000-volt high-tension cable. Connection is made between the testing station and the feeder to be tested by special flexible cables and bayonet switches. The switches and switchboard for this outfit are located in the third bay of the fourth mezzanine.

FEEDER GROUND INDICATOR.

Mounted on top and in the center of the feeder control board is the indicator of the feeder ground indicator. On each of the outgoing triplex feeders, as also on the feeders devoted to the motor-generators and exciters, are placed three special series transformers connected in series. Any unbalancing of one of these feeders which may have been caused by a ground will induce currents in these series transformers, which in turn energize a telephone drop in the indicator board. A shutter is

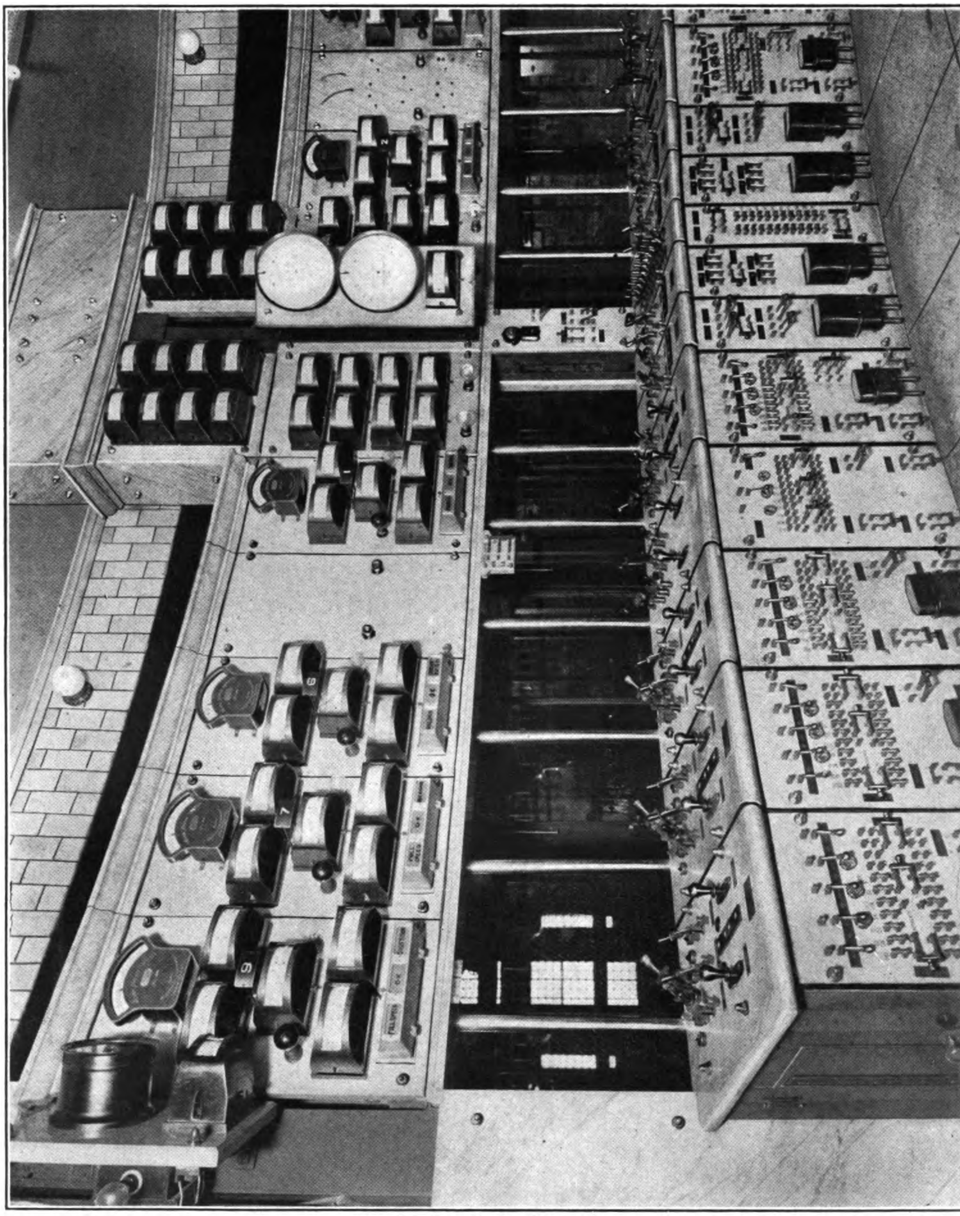


Fig. 43.—Generator Control Board, Waterside No. 2.

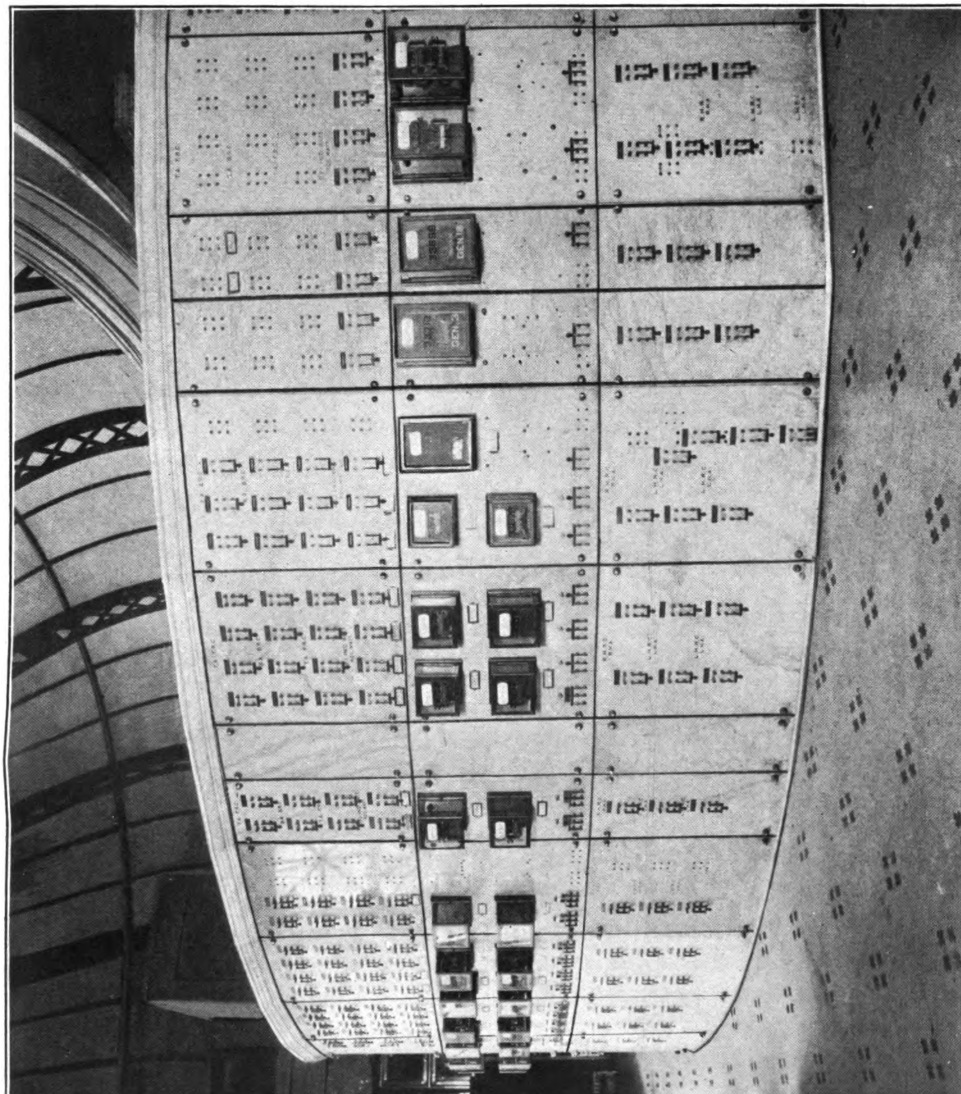


Fig. 44.—Rear View of Feeder Control Board, Waterside No. 2.

tripped, having the number of the feeder in question painted thereon; at the same time this action also closes an alarm bell and battery circuit, as well as short-circuits the main telephone drop coil.

ELECTROSTATIC GROUND DETECTOR.

Electrotstatic ground detectors are used for each section of high-tension bus. These are located in the north wall of the high-tension control switchboard room. Connection with the bus section is made through carbon resistance fuses and disconnecting switches. The alarm bell and battery circuit is made by three telephone drops mounted on the upper part of the bus tie panel.

GROUND TEST POLE AND CABLE.

At convenient places on the first, second, third and fourth mezzanines are located cabinets containing ground contact poles and cables. By means of this outfit, any portion of the high-tension system may be tested to see if it is alive or not before commencing work thereon. This ground is made through an expulsion fuse, and the continuity of the circuit may be tested through plate connection and lamp in the 110-volt lighting circuit.

EXCITER SWITCHBOARD.

This switchboard is located in the center of the main floor of the electrical galleries. It is composed of selected slate panels and moulding of blue Vermont marble finish, and is supported on a steel frame of special design. On this board the control and starting switches and instruments are located in the center, while the feeder bus sections, positive and negative, are located on either side. This board is tied in with the motor-generator light and power switchboard and with both storage batteries. From the center or starting sections are controlled the two motor-generators and the four exciters; also the electrically operated end-cell switches of both batteries.

MAIN LIGHT AND POWER BOARD.

Located at the westerly end of the main floor of the electrical galleries is the main light and power switchboard. From this board extend the feeders that serve the station with light and power. This board is connected directly with the motor generators Nos. 1 and 2 and with storage battery No. 1. It is also tied in with the exciter board, with Waterside No. 1 switchboard and with the outside Edison system. This board, like the exciter board, is composed of three sections.

STORAGE BATTERIES

The storage batteries, two in number, are located in the battery floor of the electrical galleries. They are of the R-39 type. The west battery, No. 1, has 150 cells; battery No. 2 has 140 cells. Each battery is equipped with electrically operated end-cell switches with two sliding contacts. Battery No. 1 is on the main light and power board, No. 2 is on the exciter board. The capacity of each battery at approximately 70 deg. fahr. is 2000 amp. for one hour on each side of the system.

EXCITERS, BOOSTERS AND MOTOR GENERATORS.

There are two motor-generator sets installed on the main floor of the electrical galleries for furnishing electric light and power. One is a 500-kw induction motor, 55 amp. at 6300 volts, rated at 675 hp, driving a type M. P. generator of 1667 amp. capacity at 300 volts, when running at 375 rev. per min.

The other is a 500-kw, 750-hp, three-phase, 25-cycle induction motor, driving a 500-kw, 270-volt generator with a capacity of 1856 amp. at 485 rev. per min.

In this gallery there are also located four 150-kw exciter sets. These are 150-kw generators, 555 amp. capacity at 280 volts, running at 485 rev. per min., driven by type C constant speed, 220-hp induction motors, operating 25 cycles, 6300 volts with three-phase current. As stated before, the electric light and power board is tied into the exciter board so that the motor-generators can be used as exciters when required.

Two boosters, one of 75 kw and one of 150 kw, and a 75-kw compensator complete the electrical equipment of this gallery.

ENGINE SIGNALS.

There are two systems of transmitting signals between the operator on the high-tension control board and the engineer at the turbine throttle, in use at this station.

First, signals relating to the governing of the turbines. These signals are transmitted through the illuminated sign located on the west wall of the engine room, and used in conjunction with the signal whistle located on the south division wall, above the crane girder.

Second, signals relating to the starting or stopping of a turbine. These signals are transmitted by means of the previously mentioned signal stands, located at the turbine throttle. This system also provides for return signals to the switchboard operator.

Besides the above there may be noted the call whistle for attendants, sounded from the direct-current switchboard on the first mezzanine and an emergency alarm whistle that may be sounded from the high-tension control board. These whistles, three in number, are of different size and pitch, and are located about 10 ft. above the crane runway on the south division wall.

And finally there is a signal system for transmitting and indicating the number of kilowatts in thousands that will be required of the station within the ensuing 15 minutes. It comprises a carriage call or registering clock and an illuminated sign board and signal bell. This system is operated between the system operator's desk in Waterside No. 1 and the boiler room in this station.

CENTRAL POWER STATION
OF THE
BROOKLYN RAPID TRANSIT CO.

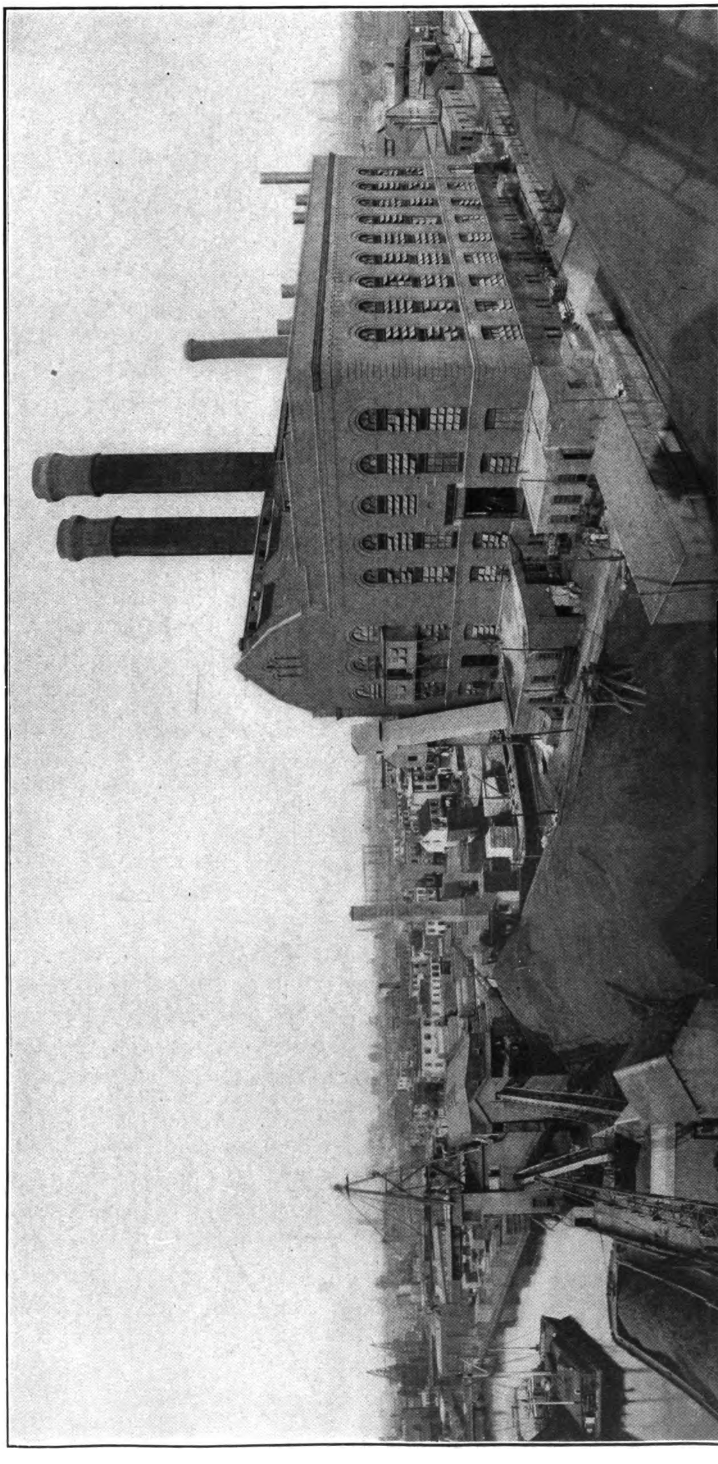


FIG. 45.—Central Power Station, B. R. T.

THE CENTRAL POWER STATION OF THE BROOKLYN RAPID TRANSIT COMPANY.

GENERAL.

Owing to the abnormal increment which, every year, is made in the demands of the Brooklyn Rapid Transit Company upon its power supply, a large increase in its generating facilities had become imperative. The system had been operated entirely by direct current, boosters being used where long distances necessitated, but the development of territory greatly removed from the power stations, as well as a desire for greater flexibility in providing for future growth in unexpected localities, led to the decision that the most satisfactory way to increase the power capacity was to adopt a system of high-tension distribution with rotary converter substations. This radical departure from the older method made possible the building of a large single station, most advantageously located for its supply of coal and water, yet able to distribute its current without excessive loss to any part of the system, and by placing the high-tension feeders underground, obviated the further stringing of heavy overhead cables. Plans for this work were made, and in the following pages a description is given of one of the principal features of the development.

The old power station, at Third Avenue and First Street, had a total capacity of 4400 kw., distributed among several different types of machinery. With the exception of two generators of 800 kw. each, which were installed in 1898, and are direct connected to cross-compound condensing engines, of 1000 hp. each, the generators in this station are of the belt-driven type. Four tandem-compound engines of 750 hp. each drive a 400-kw. generator. Three Corliss tandem-compound engines of 550 hp. each, drive three 400-kw. generators. A Corliss tandem-compound engine of 375 hp. was installed in 1896 to drive a 230-kw. booster, and a vertical compound automatic engine of 250 hp. was installed in 1898 to drive a booster of 200 kw. All the engines in this station are connected to jet condensers.

The boiler plant consists of twenty (20) Babcock & Wilcox water-tube boilers of 250 hp. each, all equipped with automatic stokers.

The site at Third Avenue and First Street was selected on account of its superior advantage as a distributing center and in addition the best facilities exist for obtaining coal, which can be received directly from the canal boats in the Gowanus Canal. The plot of ground is sufficiently large to provide for all future growth, and at the same time there is an abundance of room for the storage of coal. The building is placed adjacent to the old station and is divided into two portions, as shown in the accompanying elevation. The southern portion is used for the engine and dynamo room, and the northern portion, which is considerably higher, contains two stories of boilers, with coal storage above. The building is built entirely on piles surmounted by a concrete bed about 6 ft. in thickness. It is of red brick with bluestone trimmings. The Third Avenue front of the structure is 183 ft. 3 in. in length. The depth of the part containing the engines and dynamos is 186 ft. 9 in., and that which is occupied by the boilers is 20 ft. shorter. The boilers are arranged in banks of two, on each side of the building in two stories, six boilers being placed in each tier. There are no economizers in the station, but space is left for equipping the plant with them if desired in the future. The feed water is supplied by direct acting pumps and heated by closed feed-water heaters.

The boilers are equipped with dumping grates for hand firing. There is also installed a forced-draft system in order that the steam plant may be operated at its maximum capacity during rush hours. The coal and ash handling system is most complete. The coal conveying apparatus is capable of moving 125 tons of coal per hour, and provision has been made in the designs for duplicating this capacity if desirable. All coal is weighed before going to the coal pockets. The ashes are removed from the station by cars operated by an electric locomotive.

The first installation of exciters consists of two units. One of these machines is engine driven, the other motor driven. In addition, space has been left for a storage battery to furnish exciting current in the future if deemed desirable.

The interior of the engine room is furnished with a series of galleries to provide accommodation for the switchboard apparatus and feeders. These galleries are constructed largely of wrought iron, and are reached by an elevator and iron staircases. The

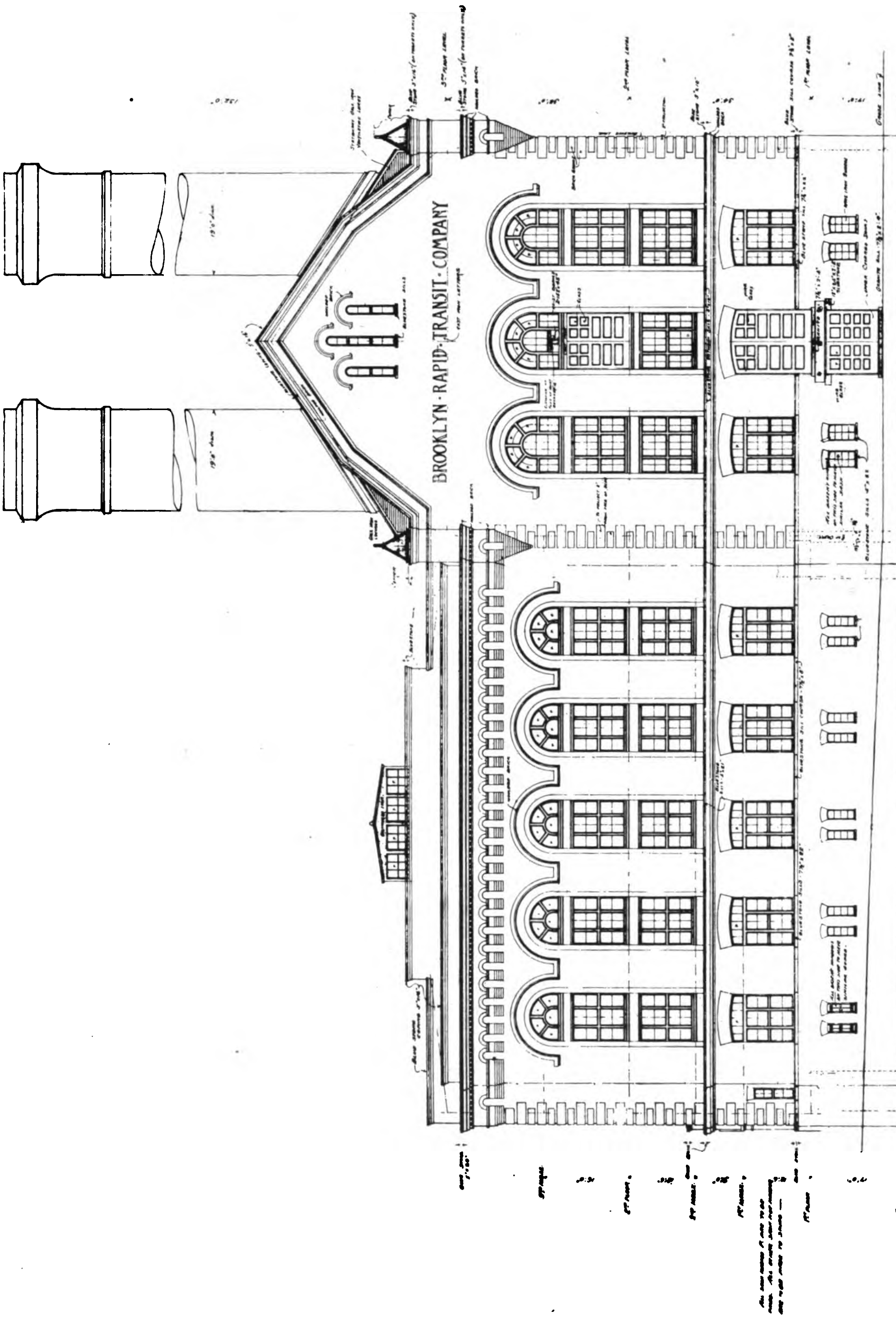


FIG. 46.—Easterly Elevation, Central Power Station, B. R. T.

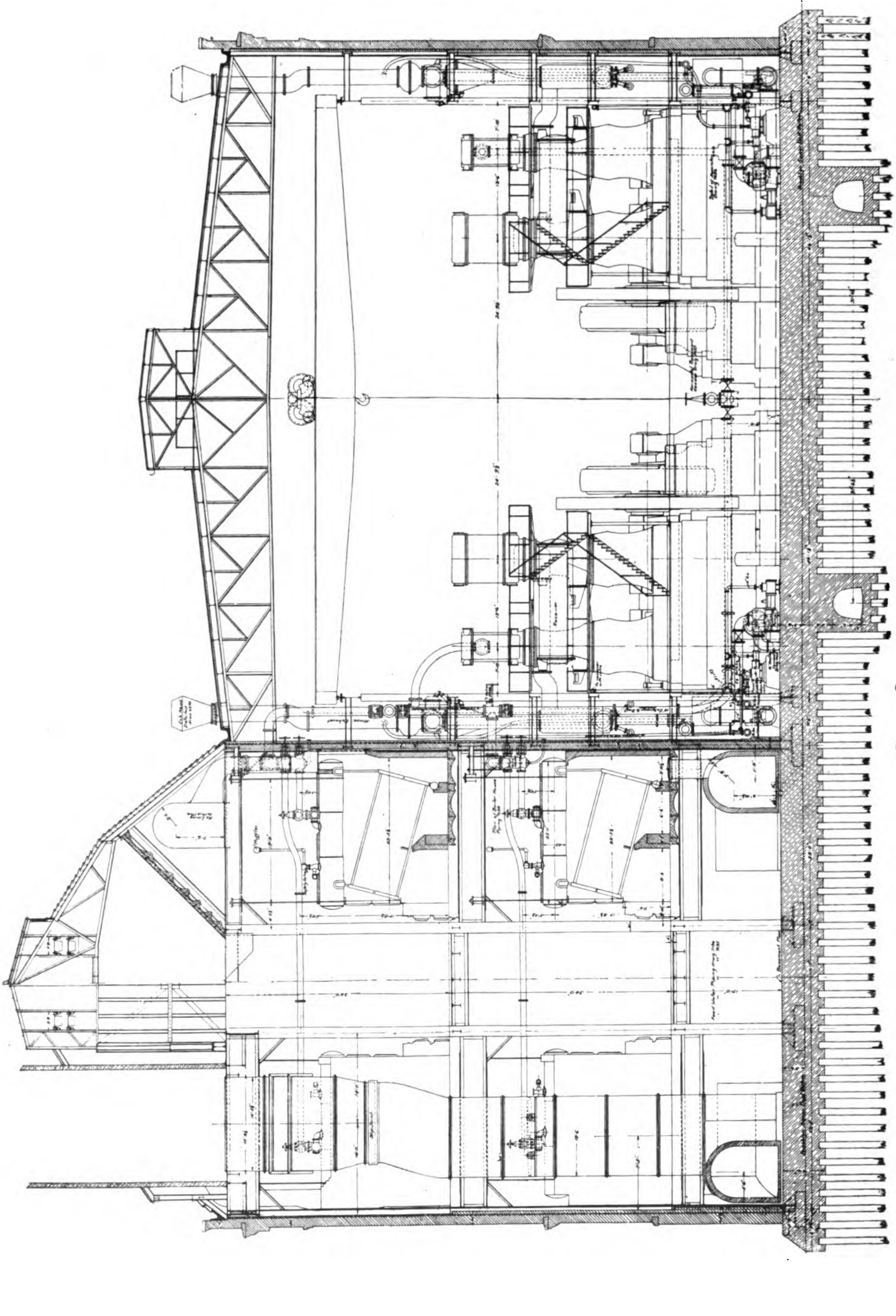


Fig. 47.—Cross Section, Central Power Station, B. R. T.

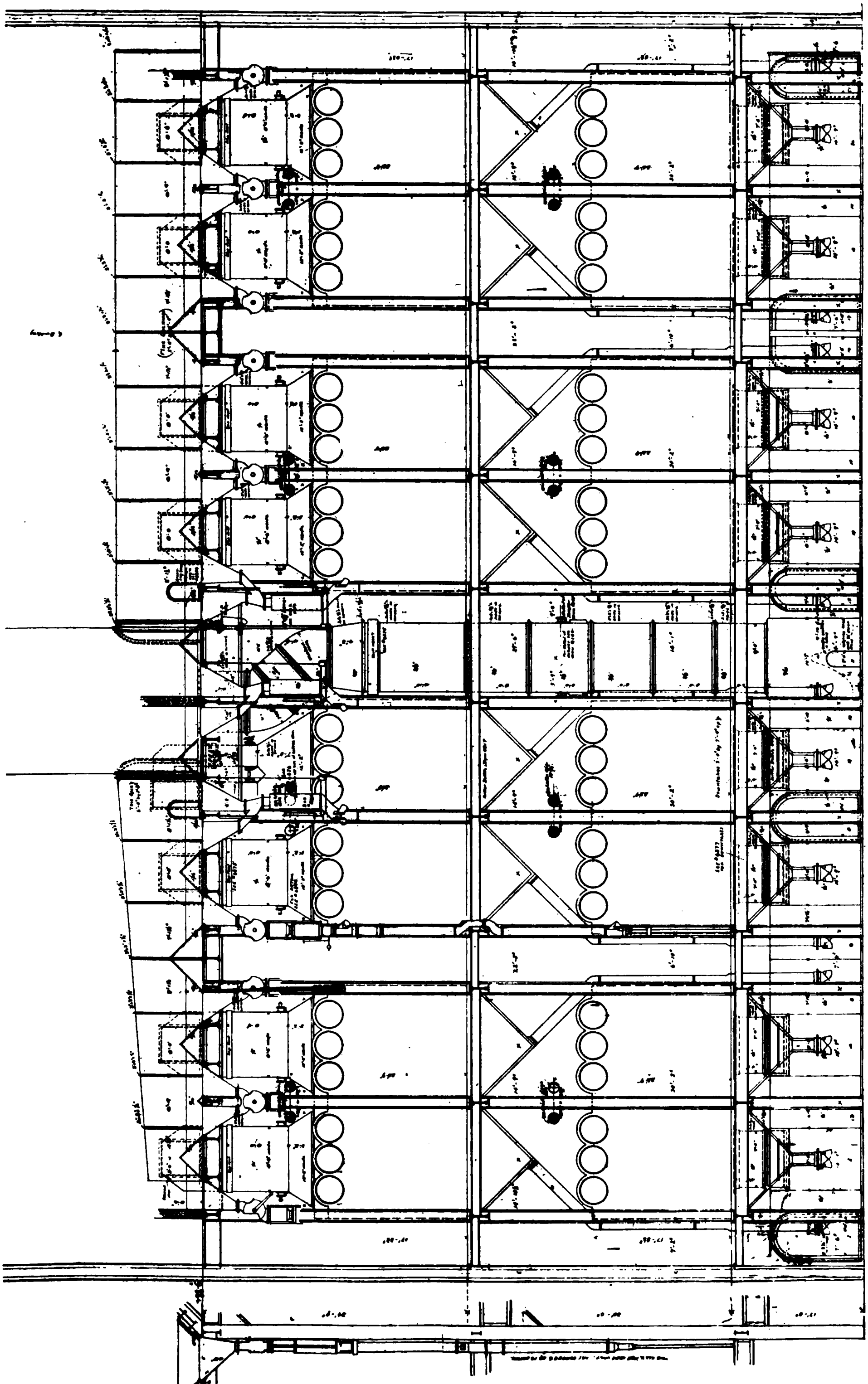


FIG. 48.—Longitudinal Section of Boiler House, Central Power Station, B. R. T.

room is lighted in a most efficient manner by large windows on the side opposite the boiler room and on the ends, as well as by a glazed monitor in the center of the roof. A 50-ton travelling crane spans the width of the room, furnishing every facility for the erection of the engines and generators and their repairs.

The entire roof over the operating and boiler rooms is filled in between the T-irons with 3 by 12 by 24-in. hard-burned terra-cotta roofing tile laid in Portland cement; covered with a slag and cement roofing.

COAL-HANDLING SYSTEM.

Coal for the station is hoisted from the barges at the dock by a 1½-ton clam shell bucket, operated by hoisting engines in a coal hoisting tower erected near the edge of the canal. The coal from the bucket falls into a receiving hopper, slides down the chute to a belt conveyor, which carries it down to the weighing hoppers in the weigh house. From here it is either carried to the coal storage piles located at the side of the station, or it passes from the receiving hopper into the coal weighing scales and thence to a bucket conveyor.

For soft coal a crusher is provided through which the coal must pass on its way to the bucket conveyor. When hard coal is being received, however, it passes from the receiving hopper directly to the scales and then to a loader, a grating being provided for this purpose in the bottom of the chute leading from the hoppers to the crusher. From the weighing hoppers the coal passes through the loader to either of two bucket conveyors which carry it up to the monitor above the bunkers, where it is dumped.

The coal tower, which is of the two man type, contains the bucket engines and trolley engines. The bucket engines are double 12 by 16-in. direct connected to double drums with clutches. The trolley engines are double 6 by 8-in. direct connected to single drums, with friction brakes. Each coal conveyor consists of an endless chain of buckets suitably connected by links and mounted on wheels. The conveyors carry the coal from the loaders through a tunnel underground up through the boiler house end to the monitor above the boiler house and thence along the monitor, discharging their contents into the bunkers at which the trips are attached.

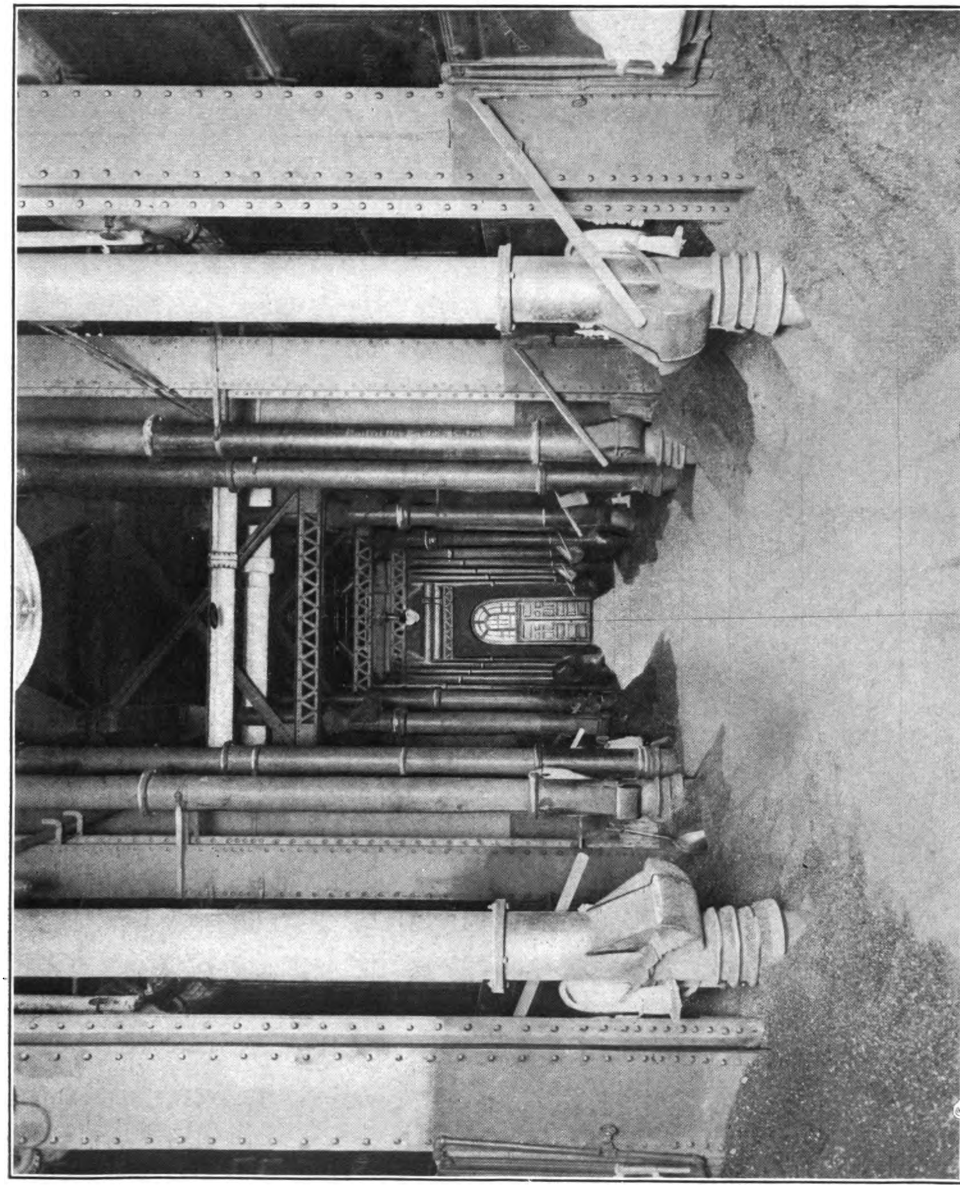


FIG. 49.—Boiler Room, Central Power Station, B. R. T.

THE ASH CONVEYING SYSTEM.

The ashes from the hoppers, under the grates of both tiers of boilers, pass down through cast iron downtakes to ash cars in the basement. The cars are then pushed along the tracks to the receiving hopper of the skip hoist in the ash handling vault (see plan). This ash handling vault is located just outside the building wall. From the vault the ashes are carried by the skip hoist and dumped into the ash pocket, which is located on the dock. From the ash pocket the ashes pass by gravity through chutes to the ash scows which are moored at the bulkhead, or the ashes can be delivered from the bottom of the pocket directly into the company's cars.

The ash pocket is of steel and concrete and is located on the dock near the bulkhead. There are telescopic chutes on the canal side for discharging the ashes into the scows and fixed chutes on the underside of the pocket for discharging into the cars.

THE STEAM GENERATING PLANT.

The steam generating plant for this station is composed of 32 water tube boilers whose weight is carried directly by the steel frame of the building.

The boilers are of the three-drum, Babcock & Wilcox type, containing 6386 sq. ft. of heating surface made up of 4-in. tubes 18 ft. long in banks of 21 sections, 14 tubes high. Each boiler has 115 sq. ft of grate surface.

Each boiler at its normal capacity will evaporate 22,000 lb. of water from and at 212 deg. fahr, per hour., equivalent to a rating of 650 hp, with an economical overload capacity of 50 per cent.

The boilers are in two tiers, 16 to a tier, eight boilers on each side of a longitudinal firing aisle.

Each section of boilers is fitted with steel plate flue and uptake. The first tier flues are of rectangular section with archtop 11 ft. 9½ in. by 9 ft. ½ in., made of ¼-in. plate with angle stiffeners, each flue serving four boilers and leading to the uptakes, which are 12 ft. 6 in. by 9 ft., built of ⅜-in. plate. The uptakes are equipped with heavy ribbed cast iron dampers and damper mechanism. The second tier boilers discharge their products of combustion through flues of rectangular section, 8 ft. 6 in. by 7 ft. to the steel stacks. The stacks, two in number, are located midway of each row of boilers. Thus each stack serves 16 boilers, eight on each floor.

The stacks are supported and braced by the steel framing of the boiler house. The height of stacks above the steel foundations is 132 ft. The total height above first floor is 200 ft. Each stack is made up of three rings 44 ft. long, consisting of 5/8, 1/2 and 3/8-in. steel plate respectively. Five annular rings support the brick lining and stiffen the stack. Each stack is lined with 8 in. of red brick, backed by 1 in. of Portland cement.

THE FORCED-DRAFT SYSTEM.

First tier boilers: There are two independent air ducts running lengthwise from east to west along the ceiling of the boiler room basement, each duct feeding eight boilers. They are supplied at each end and in the center with blowers direct connected to railway motors and vertical engines respectively. The cross section of the duct is 3 ft. 9 in. by 5 ft. 9 in., giving a gross area of 21.5 sq. ft. in length of about 147 ft. 9 in. The area of the air opening to each hopper is 9.5 sq. ft.

Second tier boilers: There are four independent air ducts running lengthwise of the building from east to west along the ceiling of the first-floor boiler room, each duct feeding four boilers and supplied at each end with blowers direct connected to railway motors. The blowers and motors are hung from the second floor. The duct areas and the areas for the hopper openings are the same as for the first tier boilers at the fans. At the ends of the ducts the areas decrease to about 5 sq. ft. in length of 64 ft.

THE ENGINES.

The power installation comprises eight 4000-hp engines direct connected to both direct and alternating current generators. They are arranged in four pairs. The engines are vertical cross-compound condensing engines, having cylinders 42 and 86 in. in diameter and a common stroke of 60 in. The cylinder ratio is therefore about 1 to 4.2. The two main cranks are set 90 degrees apart, and two other cranks are part of the transmission gear; one a drag crank, which connects the generator, and the other a small crank driving the shaft on which are the high-pressure eccentrics. The general arrangement of the cylinders, frame, generator, condenser, etc., is shown in the illustrations.

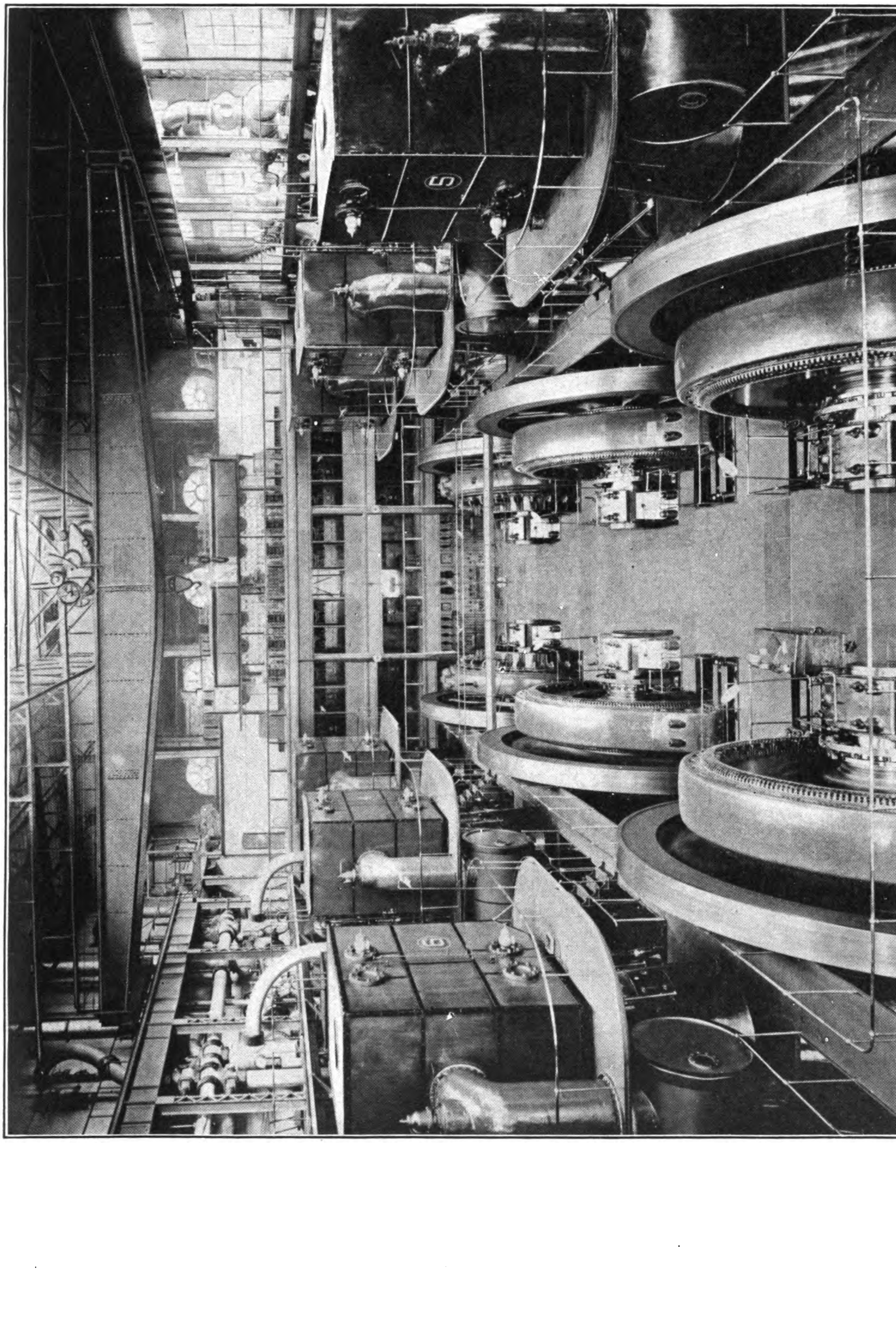


FIG. 50.—Operating Room, Central Power Station, B. R. T.

The main frames are A-shaped. The placing of the valves in the heads allows of a compact and accessible valve mechanism, and the short lengths of ports reduces the clearance to a very small amount. A reheater, with about 1800 sq. ft. of heating surface, is provided.

The valve gear is of the double-eccentric Corliss type, with the dash-pots mounted on brackets on the engine cylinder.

Both cast iron pistons are of the solid box pattern type. The main engine shaft is only 13 ft. 3¼ in. long, 28 in. in diameter at the main bearings, and the bored-out hole is 11 in. in diameter. The flywheel and generator shaft is 19 ft. 1¾ in. over all, is 36 in. in diameter in the hubs of the flywheel and generator, 32 and 30 in. at the crank and outboard bearings respectively, and the bored-out hole varies from 20 to 10 in. in diameter. An extension of the high pressure crank pin drives the high pressure solid eccentric shaft at the left, while connection between the engine shaft and the generator shaft is by means of a drag crank. The thrust of the low pressure crank pin against the drag crank is almost wholly in a tangential direction to its regular path of motion, and the cap has only to hold the bearing box in place, although it greatly strengthens the crank disk itself. The flywheel is 28 ft. outside diameter and is of the built-up type. Steam is delivered from a common main to each engine as shown, and the exhaust passes to a primary heater and to the barometric condensers mounted near the back wall. Forcd and automatic lubrications are both used.

GENERATORS.

The alternating current machines are 40-pole, three-phase, 25-cycle units, of the revolving field type, and wound to generate 6600 volts when running at 75 rev. per min.

They have a capacity of 2700 kw. with a non-inductive load at any voltage from 6000 to 6600, and they will generate this power continuously for 24 hr. without a temperature rise of more than 30 deg. cent. above the temperature of the surrounding atmosphere.

The direct connected generators are 24-pole, 575-volt, 2700-kw generators of the railway type, rated at 4700 amp. and 575 volts at 75 rev. per min.

These two generators are so designed as to regulate the voltage on approximately equal increments from an electromotive force of 525 volts at no load to 575 or 585 volts at full load, or 550 volts at no load to 575 or 590 volts.

The generators are controlled and the load distributed by a switchboard of size and type necessary for an electric railroad power station of this type.

THE HIGH-PRESSURE STEAM PIPING SYSTEM.

Over each boiler connecting the three drums is a cross-over pipe, equipped with automatic stop and check valves. From each cross-over, a 10-in. bent pipe, for expansion, connects the boiler to the stop valve header. The stop valve headers, 16 in number, are cross-connected in groups of two. The headers are castings of special design, 17½ in. internal diameter with a 14-in. flanged outlet, and two 10-in. inlets for the boiler connections.

The operating room header is a 14-in. pipe line, running along the division wall, to which are attached the various drops to the engine separators. Four 14-in. cross valves connect the engines Nos. 2, 4, 6 and 8. Four 14-in. drops run underneath the engine room floor to the header running longitudinally of and about midway across the basement and passing over and perpendicular to the four 14-in. steam supplies to engines Nos. 1, 3, 5 and 7, between which supplies it forms a cross connection through a 14-in. cross connection valve.

An atmospheric exhaust system for taking care of the engines and the heaters and the various auxiliary apparatus has been installed. The lines from the heaters to risers are of 30-in. cast-iron pipe. The risers are spiral riveted, galvanized iron 24 in. in diameter, ⅛ in. thick.

THE FEED WATER SYSTEM.

The city water connections, 4 in. in diameter, feed a 10-in. suction line from the storage tanks. These tanks are located outside of the building and near the Third Avenue front of the property. This 10-in. line is laid in a boxing of 2-in. plank and deep enough underground to avoid frost.

The two 4-in. city connections supply the two storage tanks through two 4-in. ball float cocks. The 10-in. suction from the

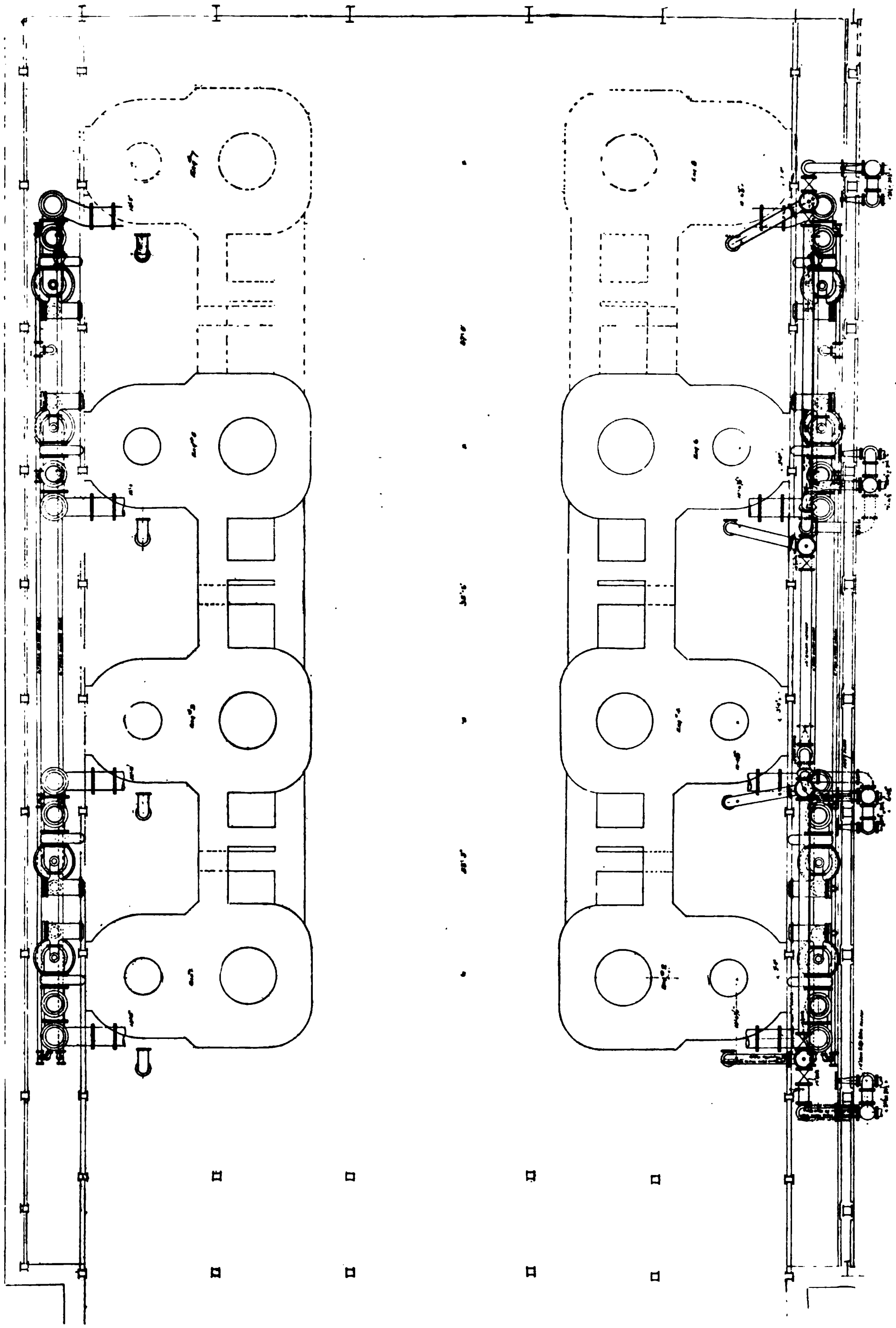


FIG. 51.—Plan of Piping on First Floor, Central Power Station, B. R. T.

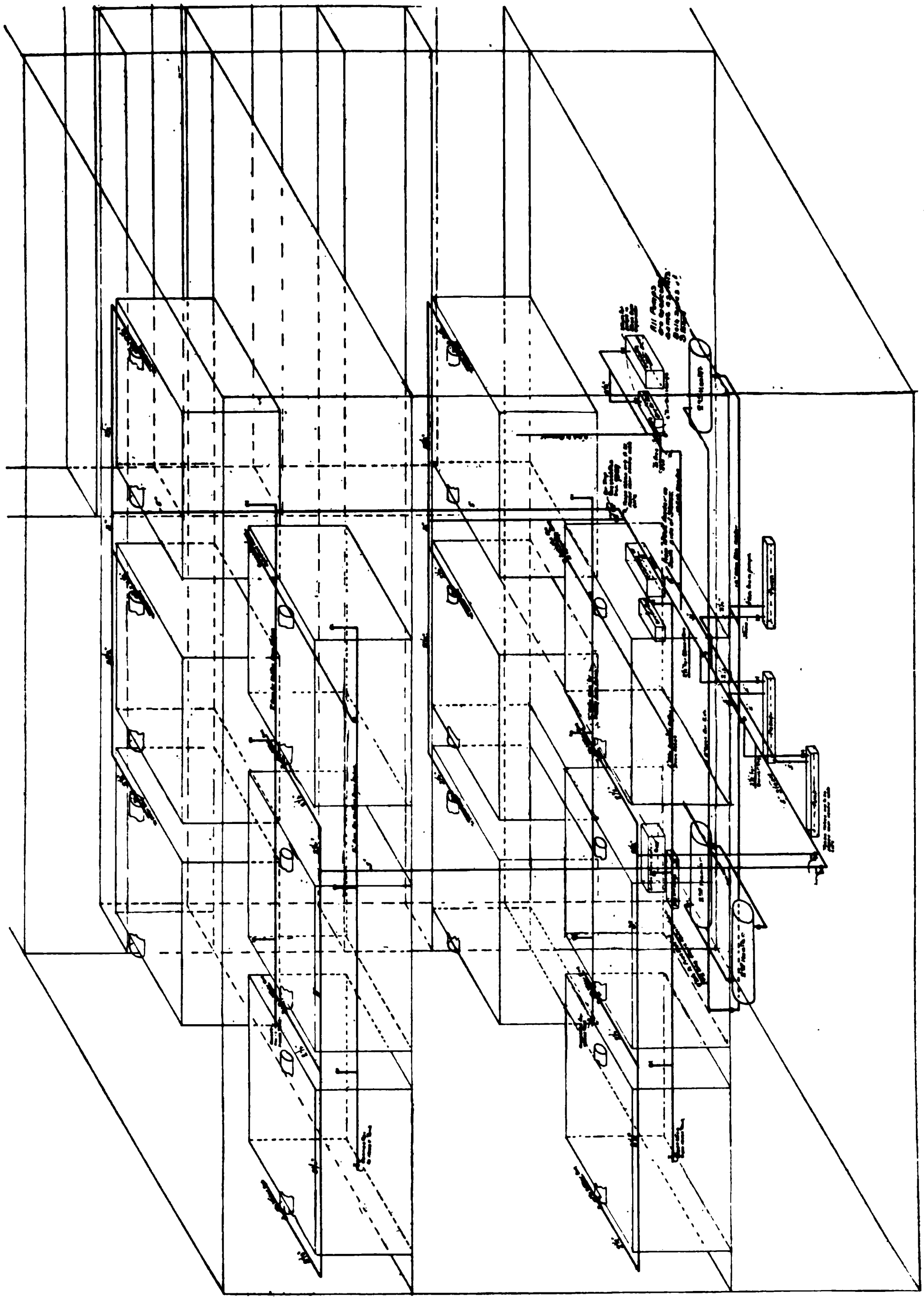


FIG. 52.—Steam and Exhaust Piping to Pumps and Heaters, Central Power Station, B. R. T.

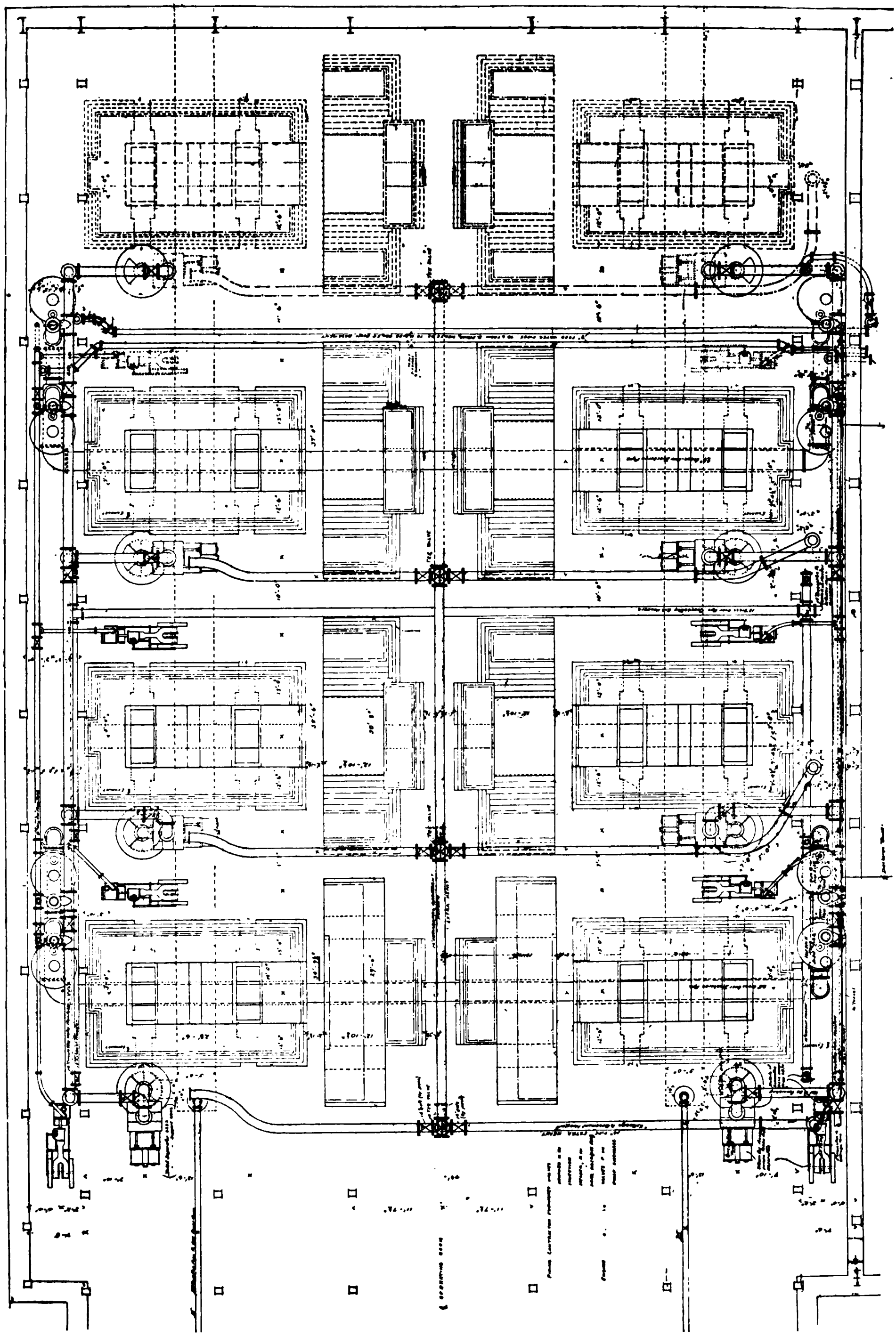


Fig. 53.—Plan of Feed Piping in Operating Room, Basement, Central Power Station, B. R. T.

tank divides inside the building and runs as a 10-in. line on each side to the four feed pumps, with a 10-in. valved connection to each line from its nearest storage tank. The lines terminate west of the western pair of feed pumps, with blank flanges and 10-in. cross connections between the two lines. The 6-in. valved pump discharges connect with two 8-in. cold water mains. These mains are cross connected through the operating room basement to the manifolds of the primary feed water heaters. The manifolds are 6-in. in size and by-passed. From these manifolds the feed water from the primary heaters is taken by two 8-in. cross connections back to the boiler house basement to two 8-in. hot water mains, one on each side of the secondary heaters and connected thereto.

The discharges from the secondary heaters are led into 8-in. risers connected to 8-in. feed mains directly under each boiler-room floor. From these mains 8-in. risers and mains feed the 3-in. cross pipe connections to each boiler. The primary heaters are vertical, even flow, water tube heaters, with 800 sq. ft. of heating surface made up of 198 1½-in. corrugated copper tubes 9 ft. long. The exhaust inlet and outlet are each 30 in. in diameter. The feed water supply line is 5 in.

The secondary heaters, four in number, are of the cylindrical water tube type. They contain 264 1½-in. seamless corrugated copper tubes 12 ft. long, making a heating surface of 1350 sq. ft. These heaters are rated at 4000 hp.

CONDENSING SYSTEM.

Each engine is equipped with an independent jet condenser, engine-driven circulating pumps and dry vacuum pump.

The circulating water, taken from a point below the power house on Gowanus canal, is converted by the suction intake tunnel to the circulating pumps. The suction on the circulating pumps is 16 in. in diameter. The tail water is discharged through the discharge tunnels on the north side of the station to the lateral canal. The dry vacuum connections to the condensers are 4 in., the discharge from the pumps to the free exhaust risers are 6 in. The hot well tanks made of ½-in. sheet steel are 6 ft. in diameter by 7 ft. 9 in. in height.

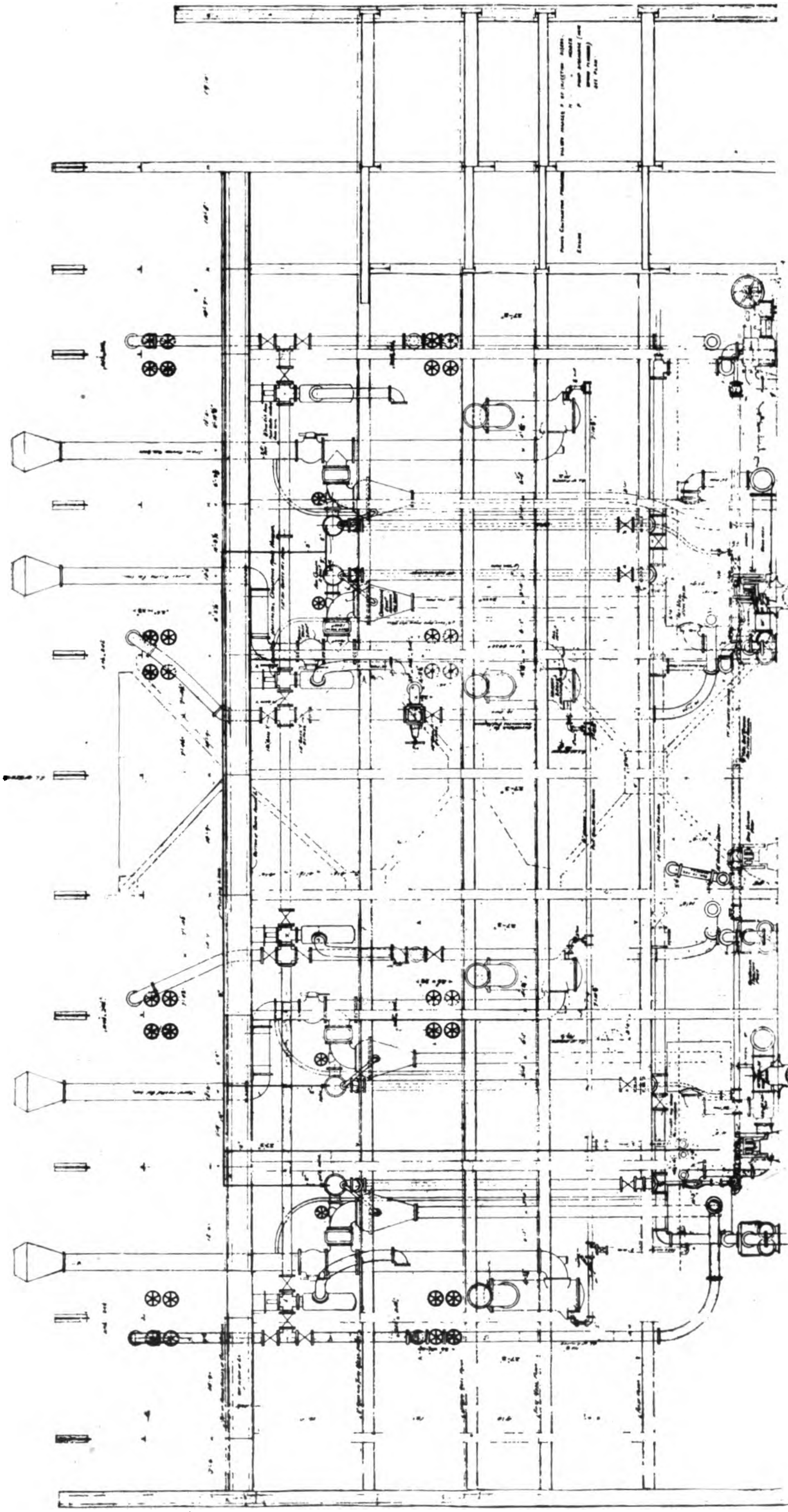


FIG. 54.—Elevation of Condensers and Their Connections on Boiler Room Side, Central Power Station, B. R. T.

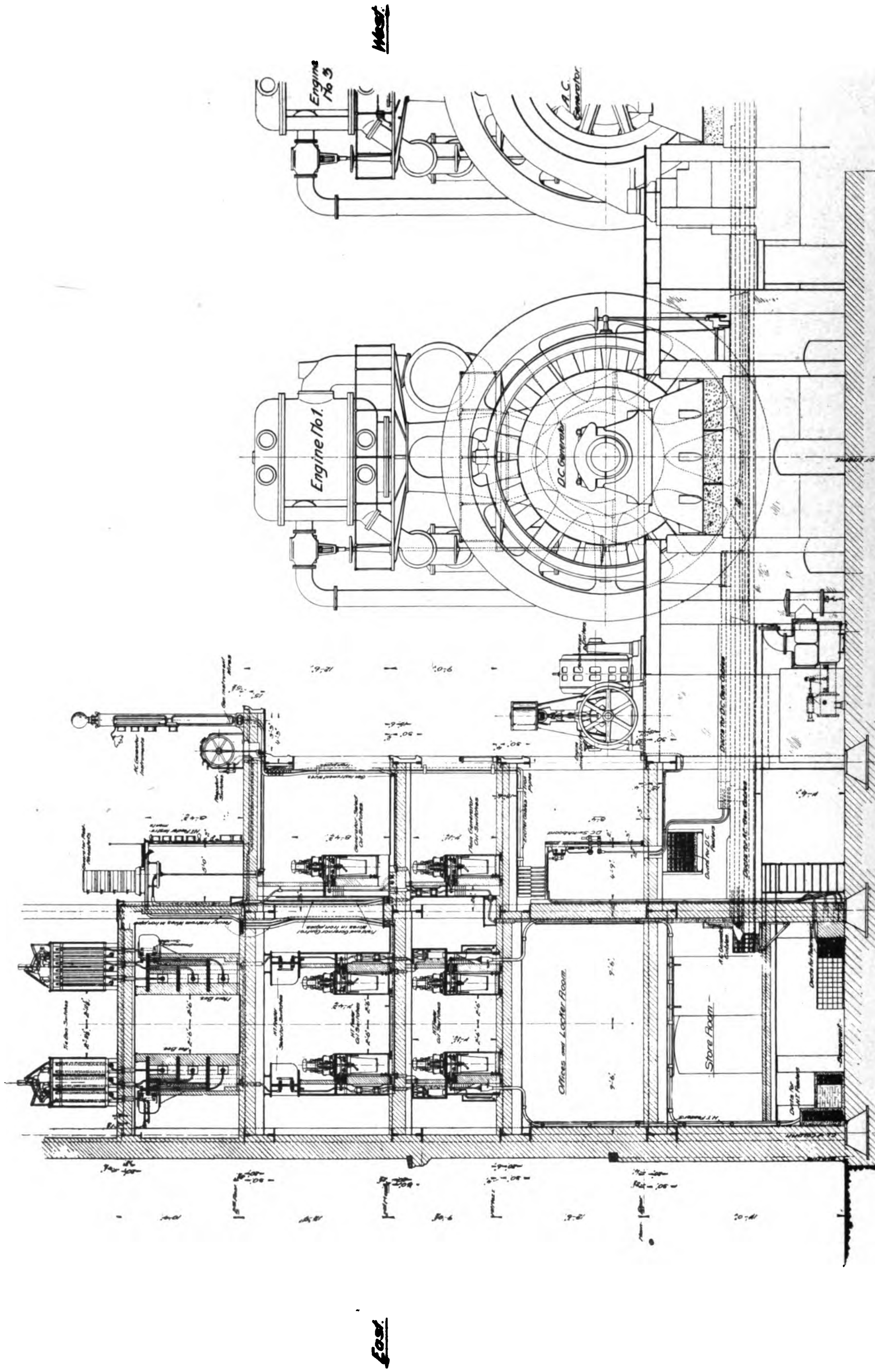


FIG. 55.—Cross Section through Electrical Galleries, Central Power Station, B. R. T.

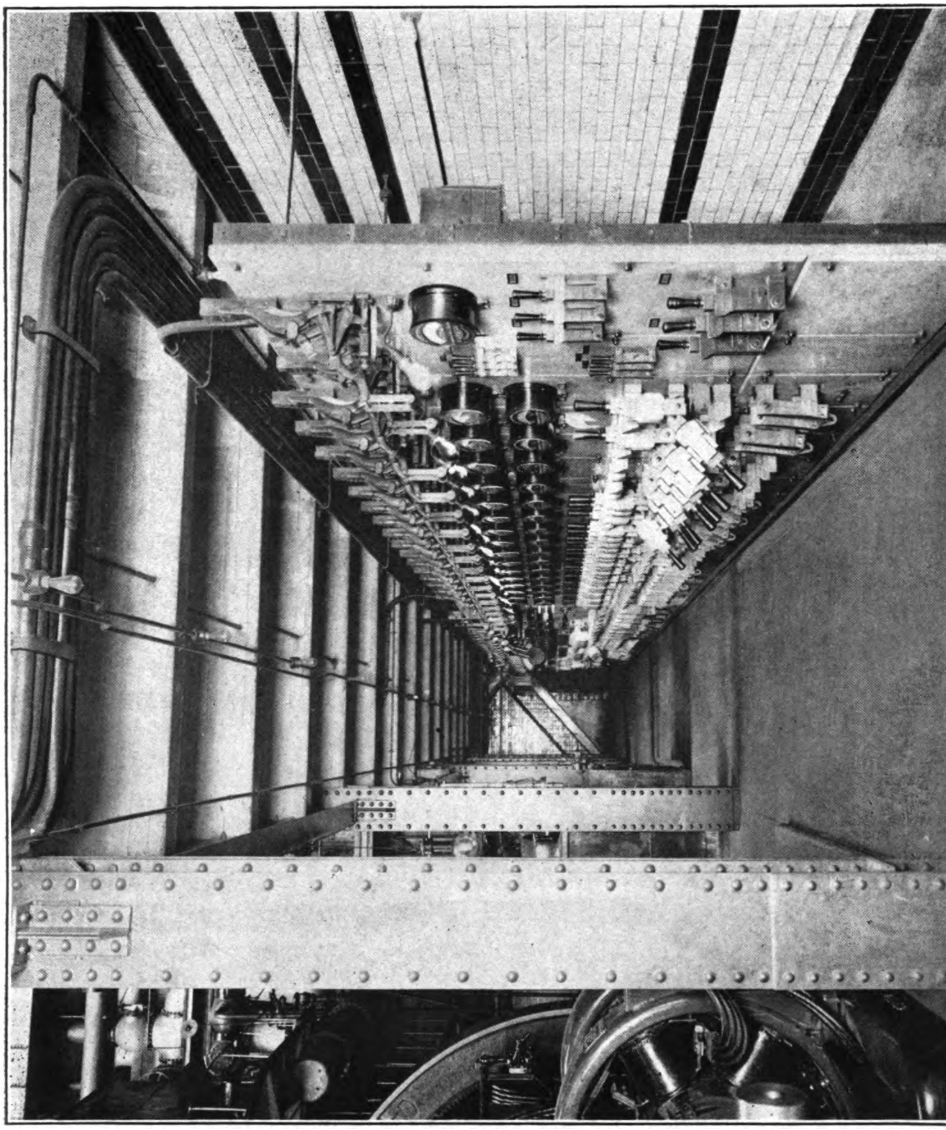


FIG. 56.—Low-Tension Switchboard, Central Power Station, B. R. T.

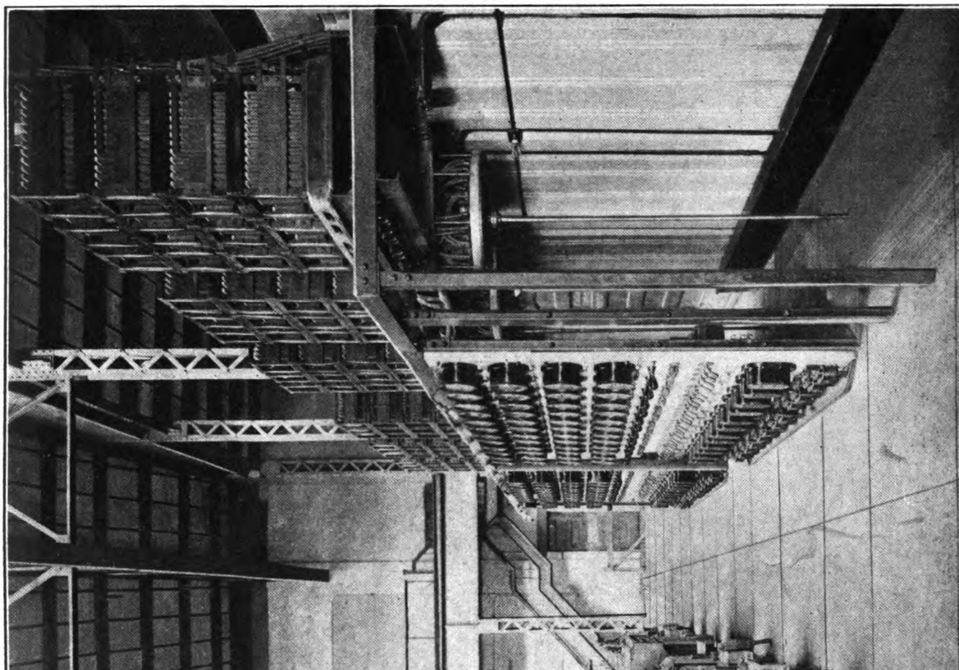


FIG. 57.—High-Tension Control Switchboard, Central Power Station, B. R. T.

SWITCHBOARDS AND ELECTRICAL CONTROL APPARATUS.

The switchboards and switchboard apparatus are located on the two floors and three mezzanines of the electrical galleries located at the eastern end of the power station.

On the first floor of the electrical galleries are installed four 150-kw, 125-volt exciters, one booster, the 600-volt direct current switchboard and the exciter board. One exciter is driven by a vertical engine and each of the other three exciters is driven by an induction motor. Two of the motors are of 200 hp, 6300 volts, 25-cycle, three-phase, 485 rev. per min. each, and are fed by one 6600-volt feeder. The third motor is of 200 hp, 400 volts, 25-cycle, three-phase, 490 rev. per min., fed by a 6600-volt feeder, stepping down through a three-phase transformer to 400 volts.

The storage battery is located in a small building erected outside of the power house. The 6600-volt generator leads run from the alternating current generators in a cable duct run build underneath the main floor and turn up in recesses in a wall built behind the direct current board, up to the front part of the first mezzanine where the main generator oil switches are located. From the main generator switches the cables run straight up to the second mezzanine, where they are split, making connections to generator selector oil switches connecting each generator to a main and an auxiliary bus, each being cut in two parts and tied through oil circuit breakers, located on the fourth mezzanine. The alternating current buses are located on the rear (eastern) part of the third mezzanine or called also second floor. Behind each set of buses are mounted disconnecting knife switches.

From the alternating current buses leads run down to the rear of the second mezzanine, where the alternating current feeder oil circuit breakers are located in two rows, each row being divided again in two parts. In the rear of the feeder oil circuit breakers are mounted selector knife switches, six knife switches to one feeder oil circuit breaker, connecting each feeder circuit breaker to either bus. The selector knife switches are provided with a mechanical device which prevents the feeder switch from being connected at the same time to both buses.

From the feeder oil circuit breakers on the second mezzanine the leads run straight down to feeder oil circuit breakers on the first mezzanine, in series with the feeder oil circuit breakers on the second mezzanine.

In the rear of the feeder oil circuit breakers on the first mezzanine the feeder end bells are located, from which the high-tension feeders are run in recesses in the building wall, down to the basement, and out of the station through the vitrified tile duct run.

All the oil circuit breakers are mounted in brick and alberene stone compartments, in which also the current and potential transformers are accommodated.

The high-tension generator and feeder control board is located on the third mezzanine or second floor.

THE
WILLIAMSBURG POWER STATION

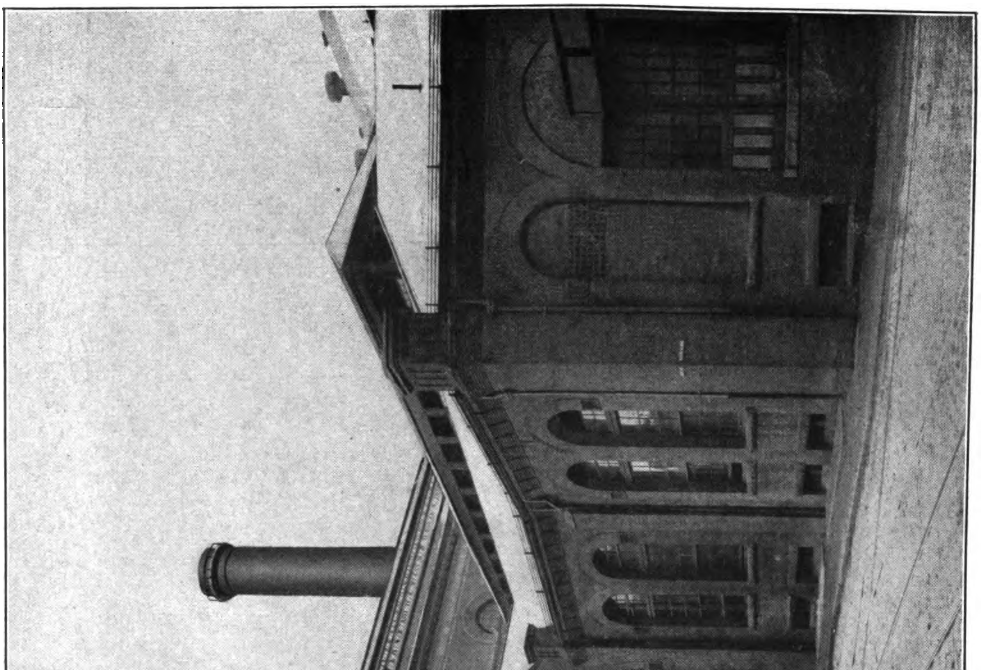


Fig. 58.—Williamsburg Power Station.

WILLIAMSBURG POWER STATION.

GENERAL.

While the latest high-tension station of the Transit Development Company was not originally included in the general plan of the power improvements, of which the Central station was the direct result, yet the latter had not approached completion before the power station possibilities of the Kent Avenue property were investigated and a preliminary report presented which recommended that a new high-tension station be constructed on the property.

The property presented for consideration consisted of the lot of land lying south of the Eastern power station of the company, fronting for about 199 ft. on Kent Avenue, 255 ft. along the southern line of the Eastern power station property, 239 ft. 10 in. on the bulkhead line of the Wallabout channel, and 332 ft. 8 in. along private property lying to the south. It covers an area of about 62,800 sq. ft. Test borings showed a solid sand bottom good for about 2 tons per sq. ft., at a reasonable depth at the eastern end of the lot, the depth of the sand stratum slowly increasing toward the western end, and sinking abruptly near the bulkhead. Below this sand stratum a good gravel is encountered.

Several layouts were considered, both of engines and boilers, and after careful study of the situation horizontal steam turbines were decided upon for the prime movers. The boiler house was arranged for cross firing aisles.

The operating room runs the length of the building on the north side. Nine turbines are installed, set side by side across the operating room—the five western units being of 10,000 kw capacity, the remaining four of 7,500 kw capacity.

The exciter sets and motor-generators are on the north side of the room on the main floor. Above these are the various electrical galleries, the station storage battery room, oil tanks and switchboards. There are two engine room cranes of 50 and 75 tons capacity, respectively.

The basement under the operating room contains the condensing apparatus, auxiliaries and piping, the oil pump room, supply room and also the transformers for the local feeders.

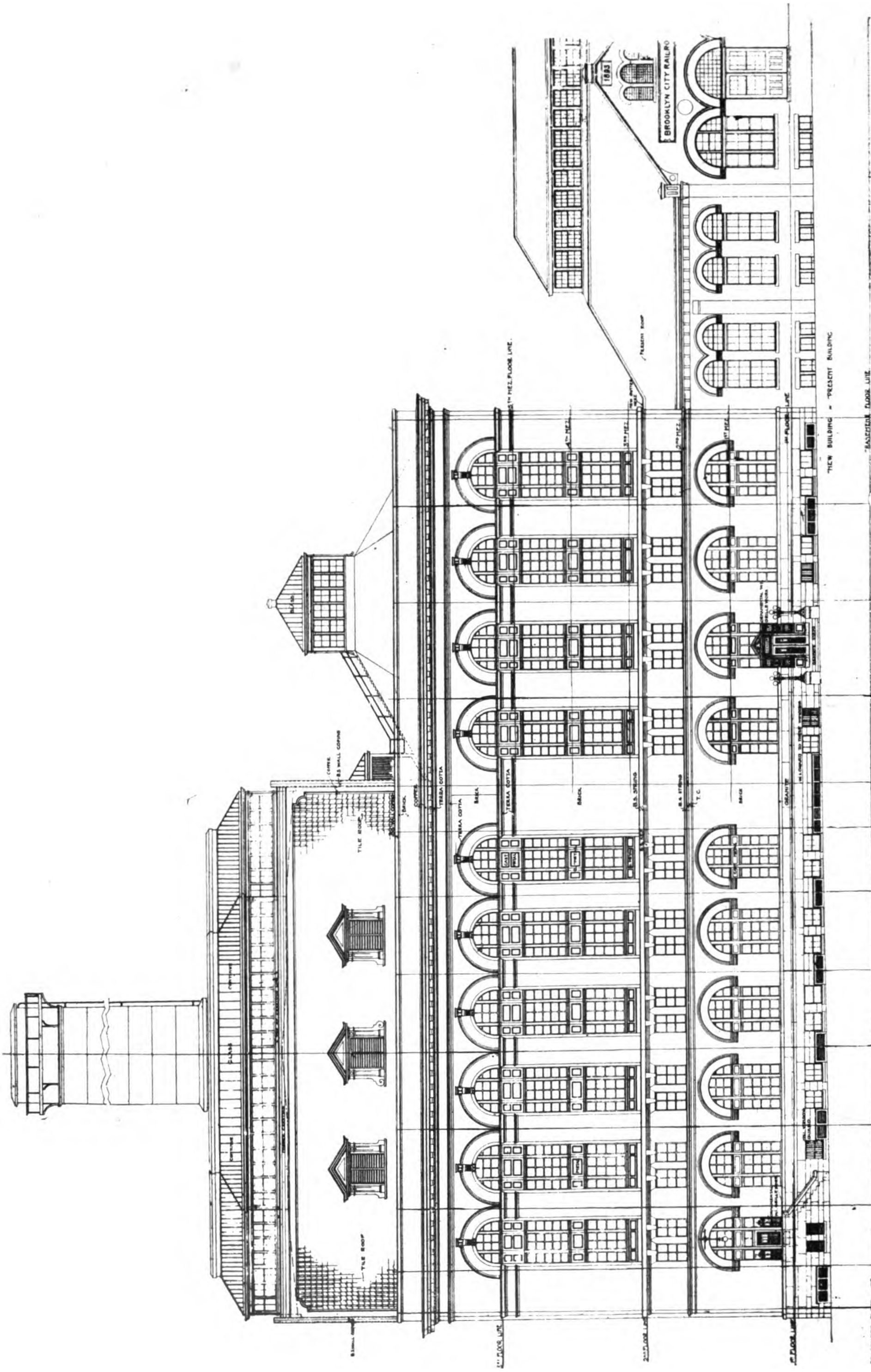


FIG. 59.—Front East Elevation, Williamsburg Station.

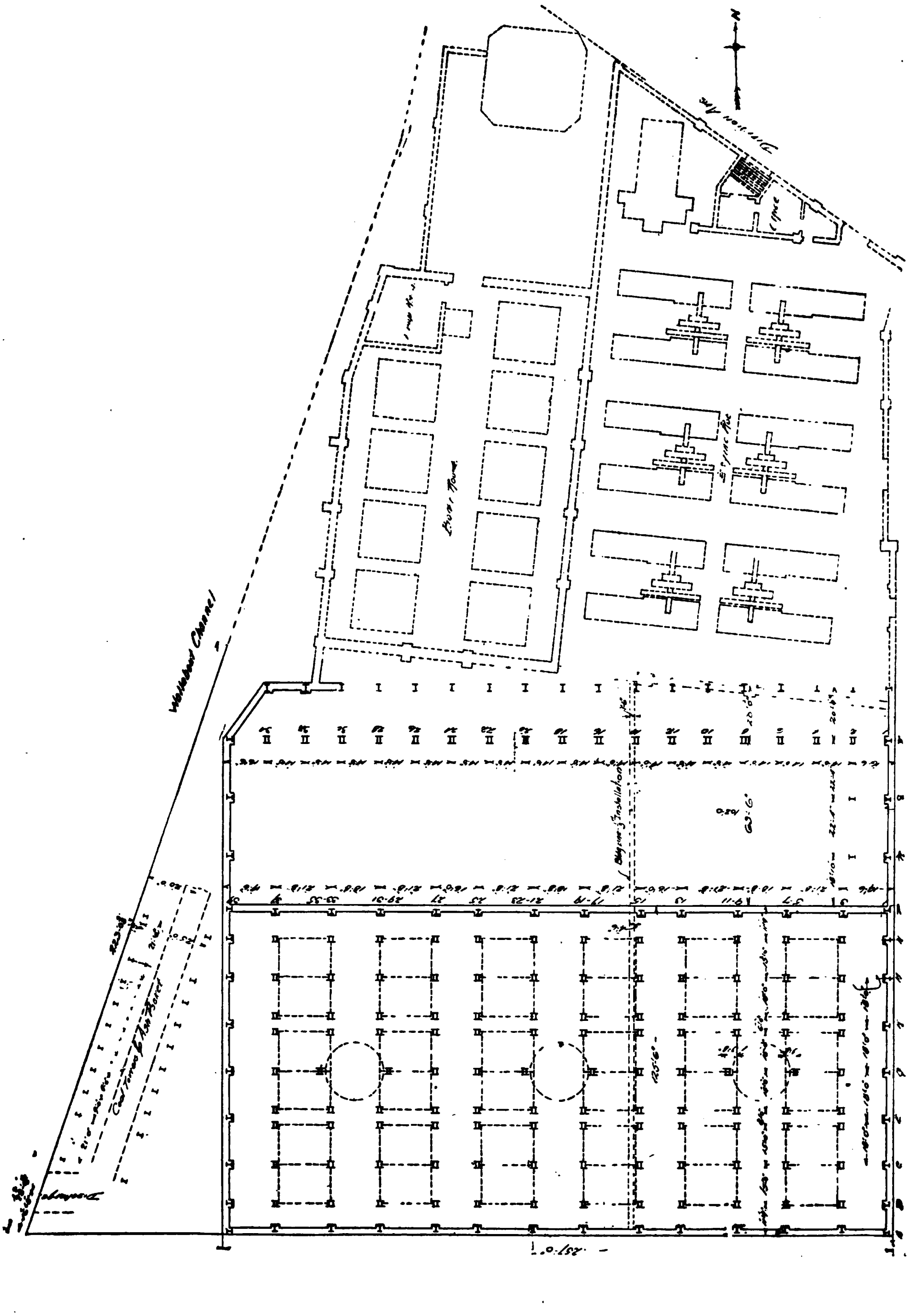


FIG. 60.—General Plan, Williamsburg Station.

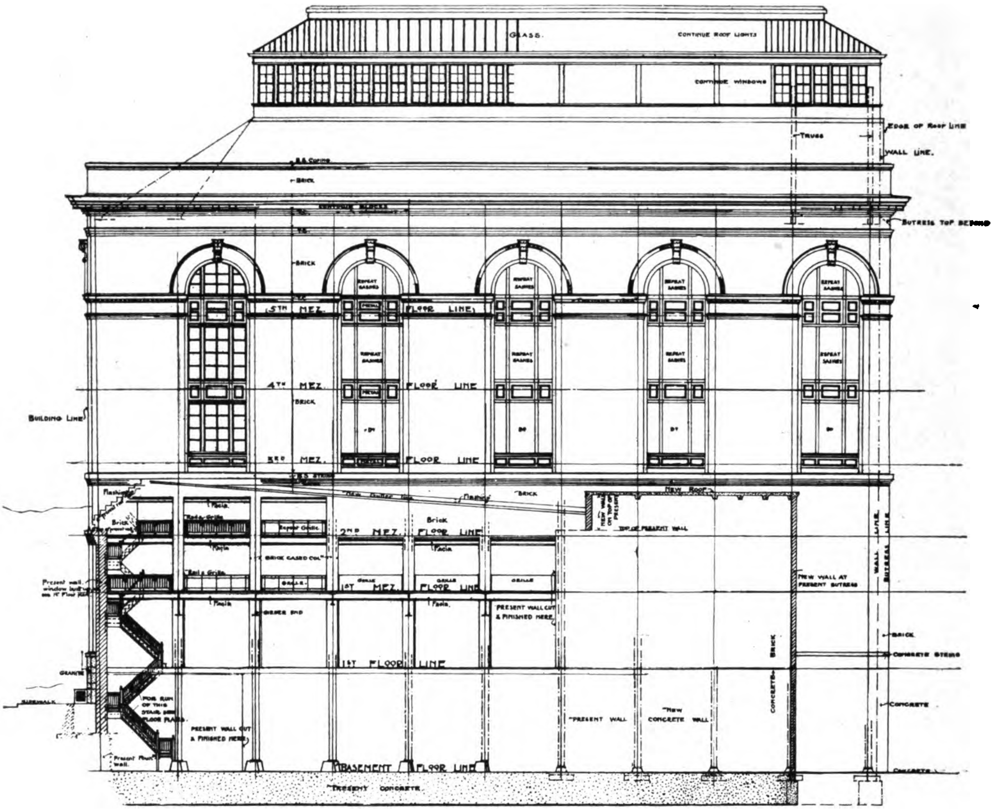


Fig. 61.—North Elevation and Section where New Building Joins Old, Williamsburg Station.

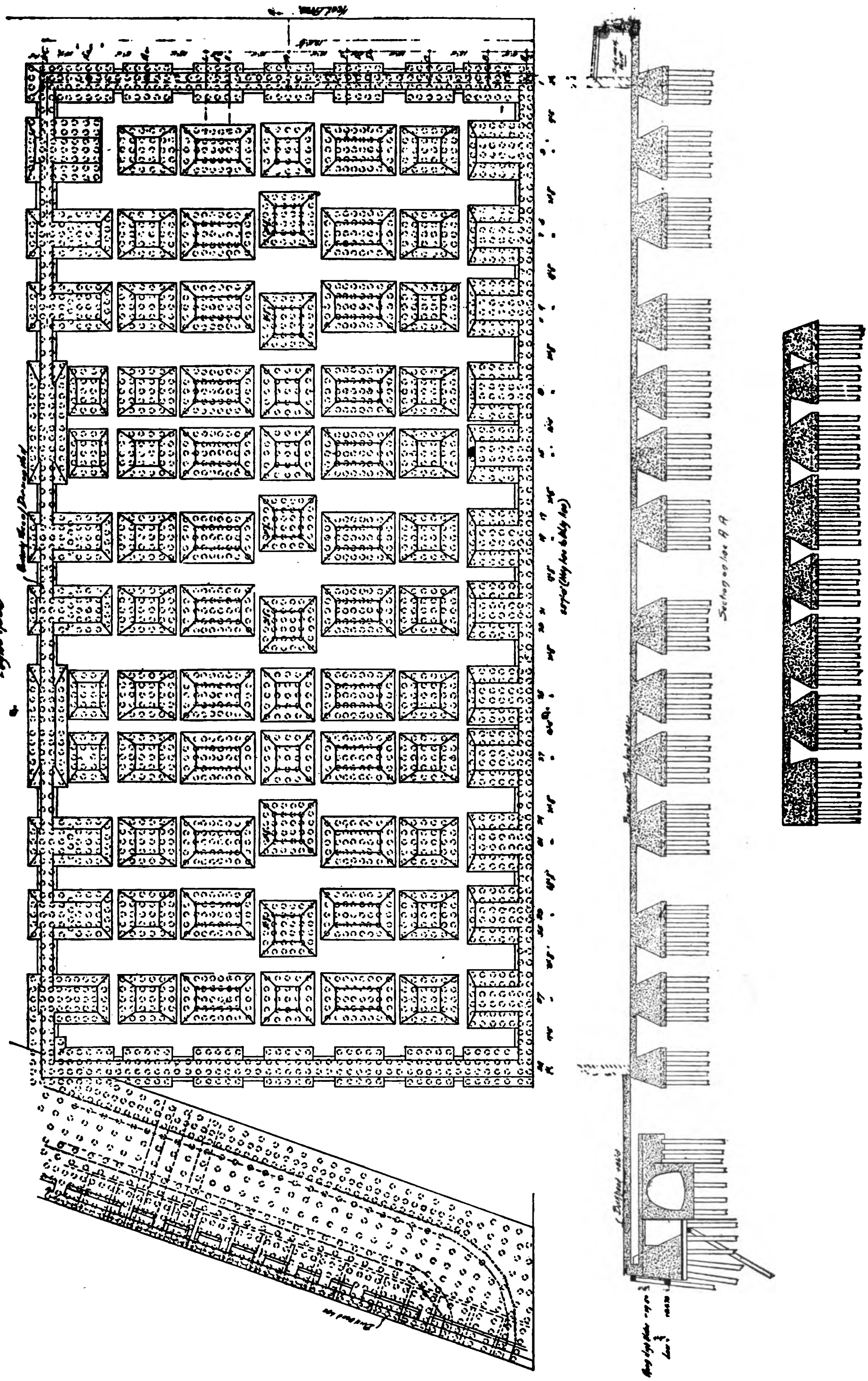


FIG. 62.—Piling and Foundation Plan, Williamsburg Station.

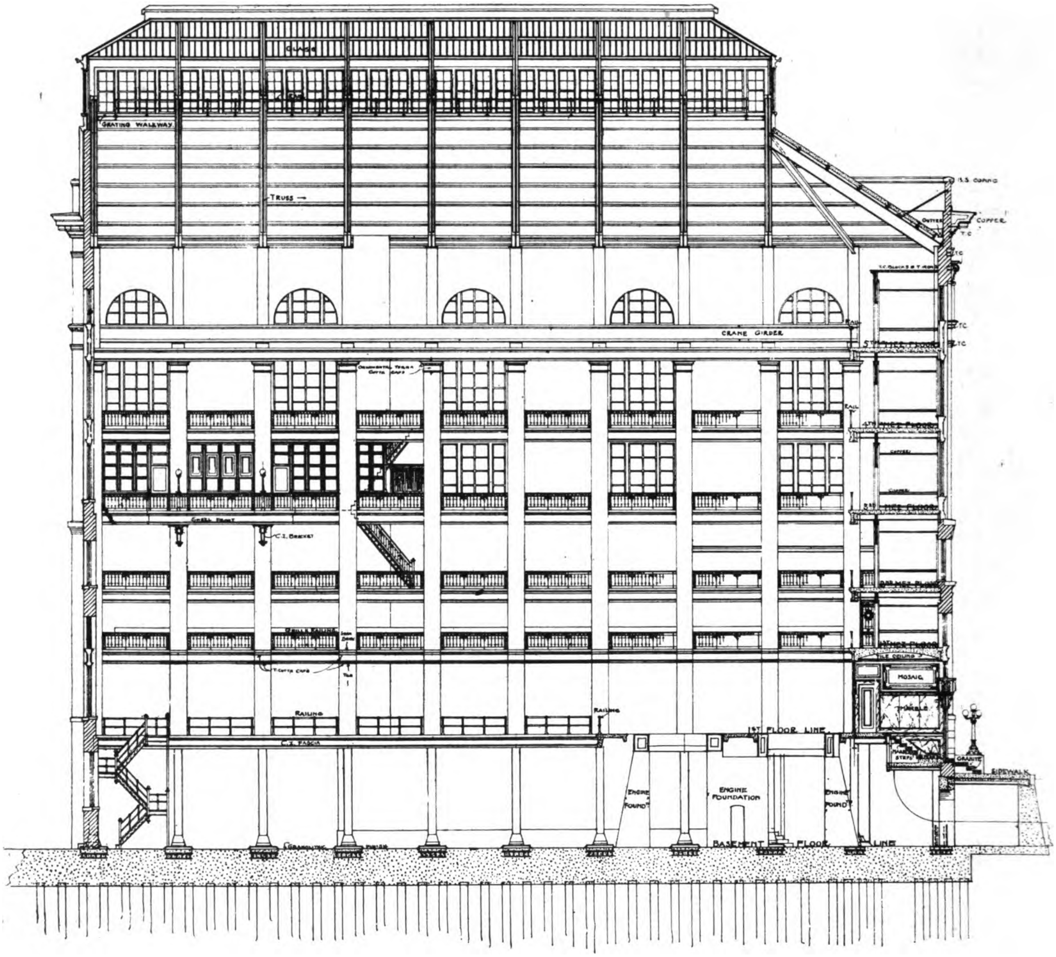


FIG. 63.—Longitudinal Section on Line E-F, Williamsburg Station.

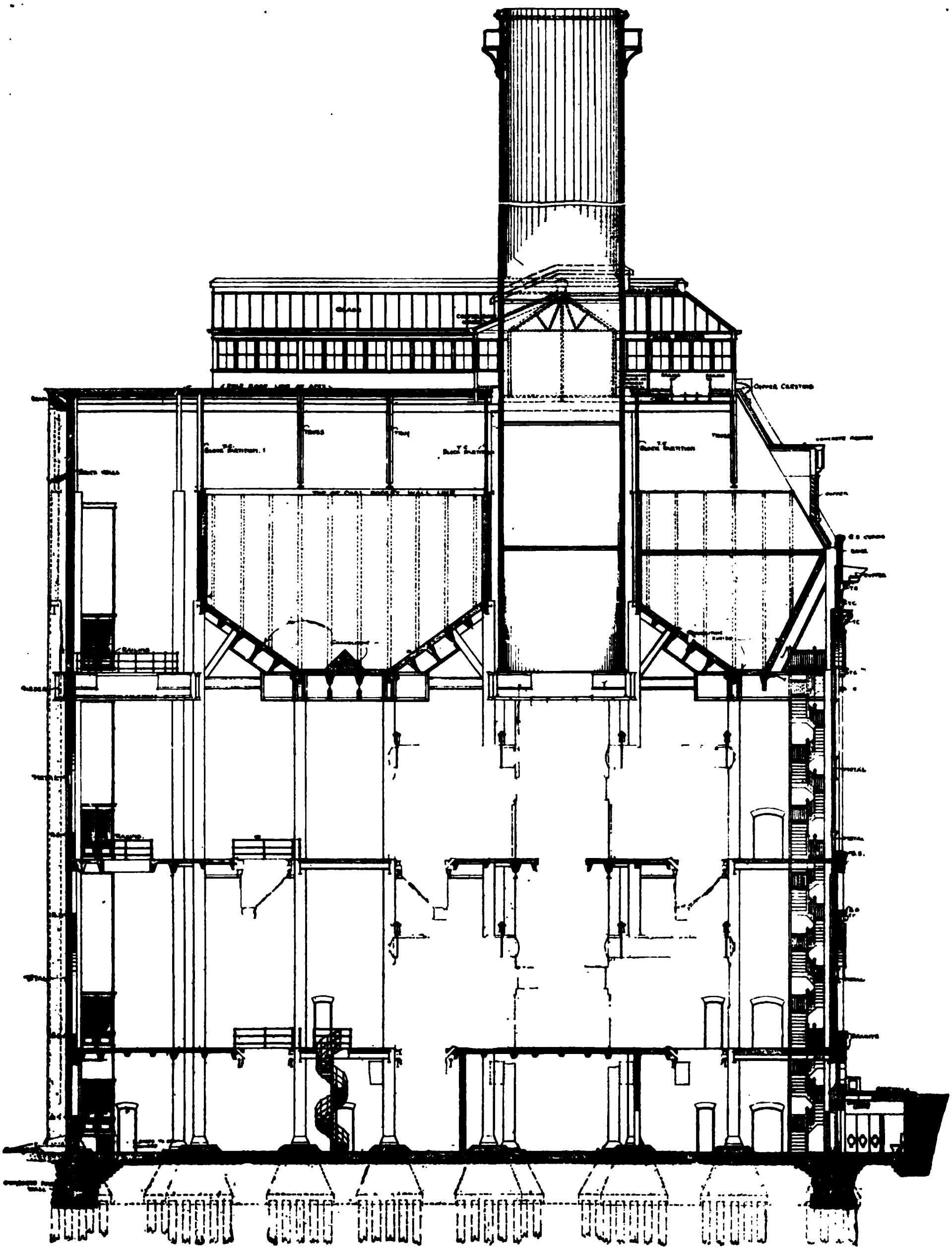


FIG. 64.—Longitudinal Section on Line C-D, Williamsburg Station.

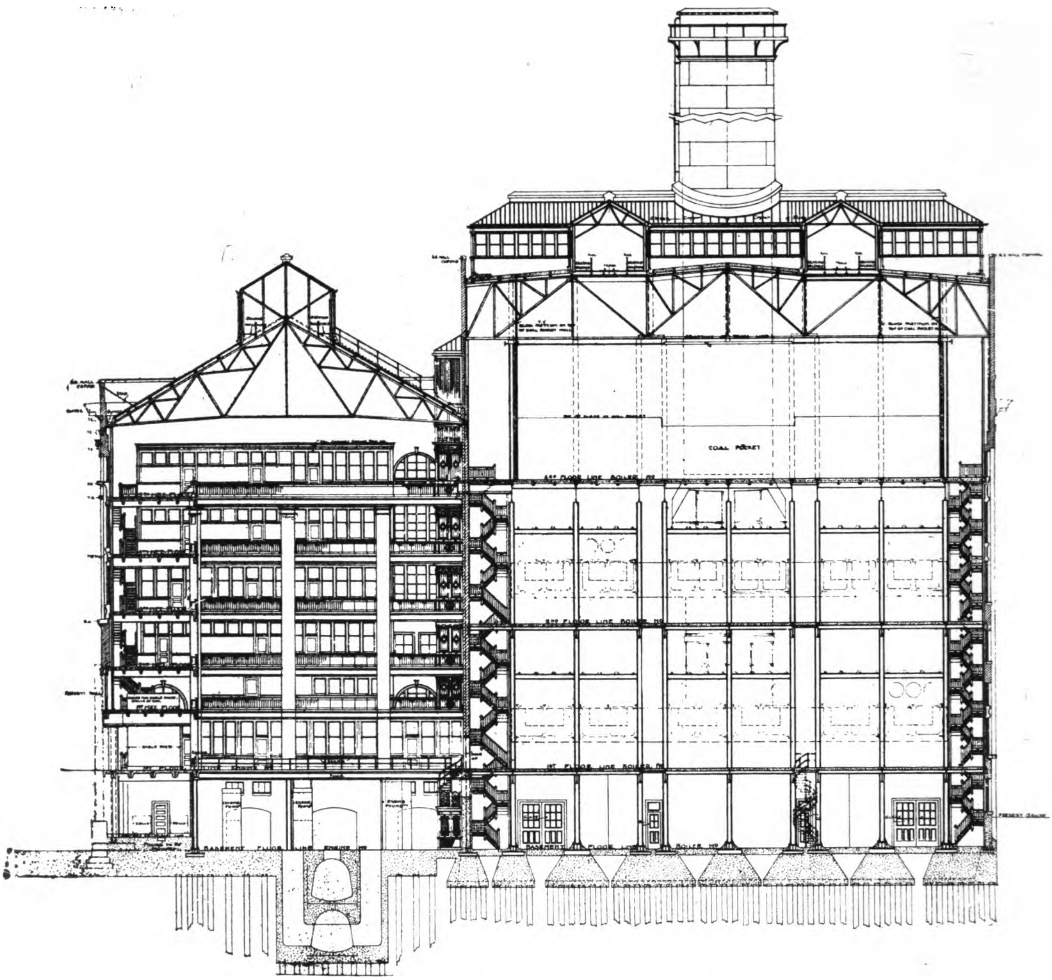


FIG. 65.—Cross Section on Line A-B, Williamsburg Station.

There are two tiers of 650 hp. Babcock and Wilcox boilers arranged in six groups of six boilers each on each floor or 72 boilers in all. There are three stacks, each stack serving twelve boilers on each floor.

The coal bunkers occupy the entire top of the boiler house above the boilers and are in turn surmounted by two monitors running the length of the roof east and west. A cross monitor at the eastern end joins these two, and furnishes the connecting link for the cable coal railway which runs in the monitors. By this system, the coal cars are carried through one monitor, across to the other and thence back to the coal tower.

The latter is set on the river bulkhead and contains the coal and ash hoppers. The ash hoppers are served by ash cars running on tracks in the basement of the boiler house, an electric trolley locomotive furnishing the traction. The basement of the boiler house also contains the blowers for the forced-draft system of the lower tier boilers, the blowers for the upper tier boilers being situated under the upper tier floor. A storage room and air compressor room extend across the basement near the center between the ash tracks.

The building is supported by a concrete monolith foundation resting on piling, the entire lot being piled. The condensing water tunnels are constructed in this monolith under the engine room. These tunnels pass under the center of the operating room, from east to west, the intake tunnel being carried to the northwest corner of the property, while the discharge tunnel goes to the southwest corner.

The bulkhead is similar in construction to that used in the Wallabout channel improvement, and is built along the entire water front, modified at the ends to allow for the construction of the screen well at the intake end and the overflow nozzle at the southern end.

Suitable foundations for the coal and ash handling and storage machinery are located between the western building walls and the bulkhead line. These foundations are tied in to the bulkhead construction.

The building proper consists of a skeleton steel frame with non-bearing walls, the steel work carrying the floor loads, bunker and stock loads.

The face or outside walls are constructed of hard, red pressed brick, trimmed with terra cotta. Two courses of moulded face brick are provided for each of the two sill courses at the level of the second and third mezzanine floors on the north and east exterior walls.

The engine room roof is sloping and is carried by steel trusses. The apex is surmounted by a monitor, for lighting and ventilating purposes. The roof over the operating room is finished with a hard vitreous flat roofing tile laid in asphalt.

The boiler house roof is a mansard finished with a flat deck, and is pierced with dormer windows. This roof is finished with a dark tinted green tile of Spanish roll pattern. On top of the flat deck of the mansard are two monitors running the length of the building, along which the cable railway runs, flanked by wings, of the same construction as the main monitors, at each stack bay. The flat deck between the monitors and up to the edge of the mansard is finished with slag roofing.

Access to the various floors is obtained by means of seven stair-wells and two electric elevators, one in the southeast corner of the engine room, the other in the northwest corner of the boiler house.

The first and second floors of the boiler house, basement floors, part of the engine room and the electrical galleries are of concrete arch construction with granolithic finish.

The removal flooring around the piping and machinery in the engine room is made up of cast iron plates. The electrical galleries and offices are of concrete arch construction finished with patent flooring.

A loading platform at the southeast end of the building, permits the handling of heavy machinery by loading from the track or scows directly on to a car which runs on to the loading platform. Here the cranes in the engine room can pick up the load and carry it to its destination. There are two cranes in the engine room, of 50 and 75 tons capacity respectively on the main hoist, and 5 and 10 tons capacity respectively on the high speed auxiliary hoist. These cranes have a span of 62 ft. 6 in. center of rails, with a vertical hoist of 81 ft. 6 in.

Two openings in the west wall of the boiler house provide for the handling of heavy machinery and supplies to the boiler house.

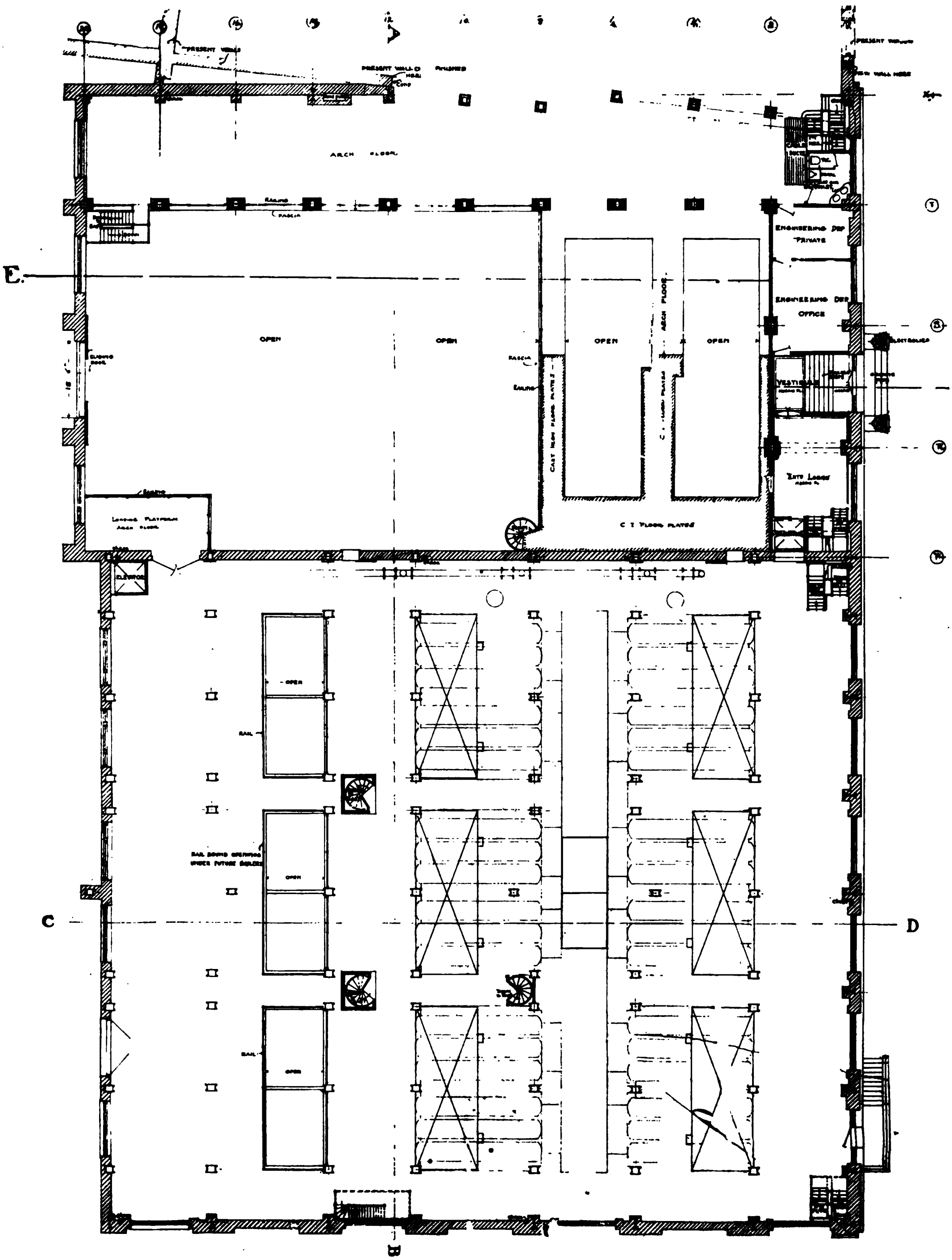


FIG. 66.—Plan of First Floor, Williamsburg Station.

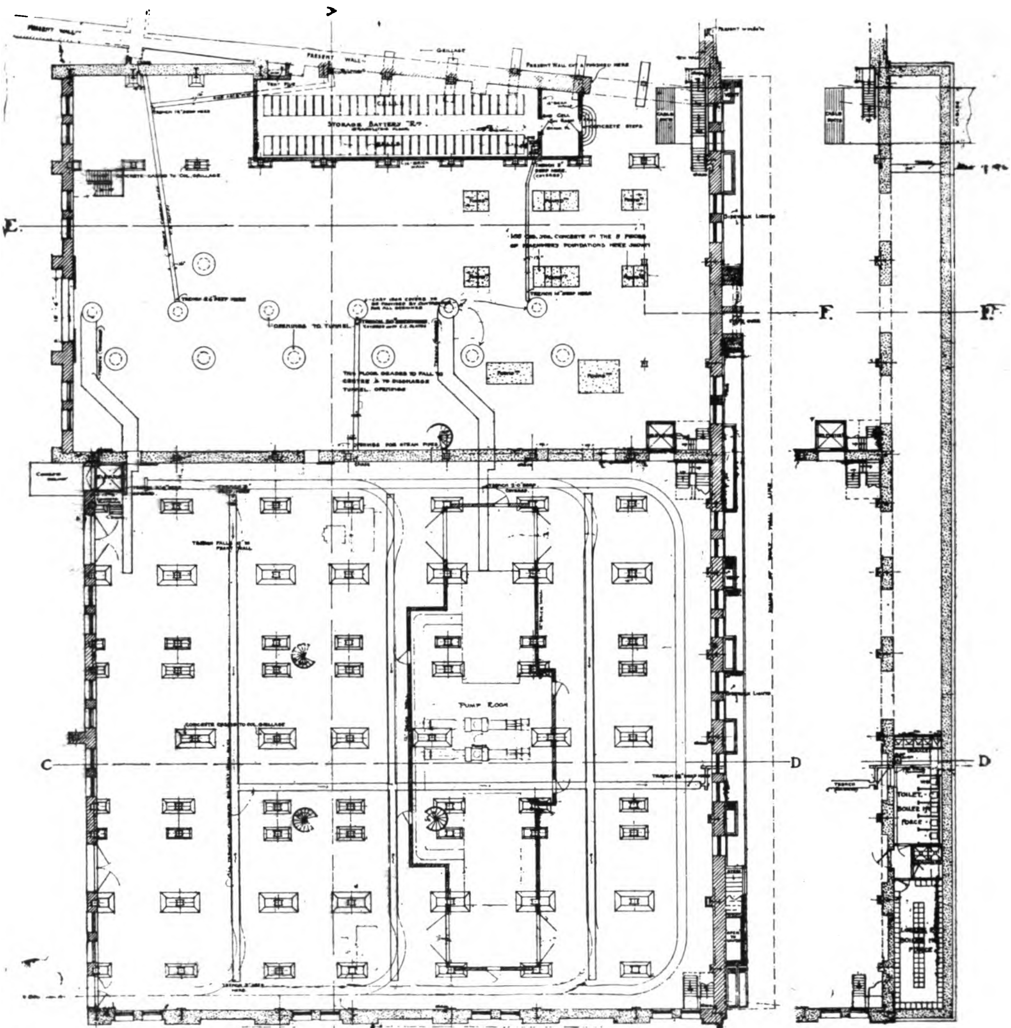


Fig. 67.—Plan of Basement Floor, Williamsburg Station.

On the bulkhead a substantial coal tower containing ash storage pockets has been erected. This tower, of the two man type, is constructed of steel and concrete and contains all the elevating, weighing and crushing machinery.

Coal is brought by barge in the Wallabout channel to the foot of the tower, where it is handled by two 1¼-ton buckets. The buckets deliver the coal to a receiving hopper, whence it falls down a chute, into a crusher (when soft coal is used) to a bucket conveyor which carries it up to the weighing hoppers at the top of the tower. From the weighing hopper the coal passes through the loader into the cable cars which carry it across the bridges, through the monitor above the coal bunkers, where it is dumped into the desired bunker.

THE ASH CONVEYING SYSTEM.

The ashes are received from the boilers of both tiers in brick lined steel hoppers, terminating in cast iron downtakes which carry them to ash cars in the basement.

The ash trackway starts from two spurs on the bulkhead, one under the ash pocket, feeding the skip hoist, the other discharging direct into the electric cars of the Ash Removal Company. The two spurs join just outside the building, enter it at the southeast corner and follow the south building wall to the front of the boiler house basement. Spurs are taken off to handle the discharge from each section of six boilers, making six spurs in all. An auxiliary spur is led from the main track into the store room, just west of the second stack.

The electric locomotives haul the ashes to the hopper of either of two systems. Under ordinary conditions the cars are dumped into a hopper at the foot of the skip hoist and then hoisted by the balance skip up to the ash pockets and discharged. From here the ashes can be discharged by gravity through telescopic chutes to the scow lying alongside or they may be drawn off at the bottom of the ash pocket into electrically operated gondolas.

In the other system the cars dump their contents into a hopper which feeds a bucket conveyor. The conveyor carries the ash up to the ash pockets and discharges it into a distributor, the method of loading from the ash pocket being the same in both cases. This latter system, however, is used for emergencies only, when the skip hoist is out of commission.

STEAM GENERATING SYSTEM.

The steam generating system consists of seventy-two 650-hp Babcock & Wilcox boilers, set double tiered, with 36 boilers to a tier, cross firing aisles. This arrangement constitutes three units of 24 boilers each, each unit divided into four sections of six boilers each, each section flanking a firing aisle.

Each unit discharges its flue gases through 8 ft. 6 in. by 8 ft. steel plate flues, to a stack.

There are three stacks, which rise to a height of 260 ft. above the street, and have a diameter at the bottom of 22 ft. 6 in., tapering at the top to 22 ft. Each stack is carried by the building and wind braced to the steel building structure. Each stack consists of five sections with angle iron stiffeners and Z-bar ring lining supports. The stacks are lined with 4 in. red brick backed with 1 in. of concrete. The plates vary in thickness from 7/16 in. to 1/4 in. The tops are finished with a cast iron cover plate made in ten sections, with lap joints.

The boilers are of the standard Babcock and Wilcox type, 3 drums, 21 tubes wide, 14 tubes high, with about 6386 sq. ft. of heating surface exclusive of the superheater. The boilers have a nominal horsepower of 650 A. S. M. E. rating. The superheater is of sufficient capacity to raise the steam 100 deg. fahr. above the temperature due to the pressure carried.

The settings are of red brick, lined with fire-brick. The fronts are of gray cast iron of standard design while the rear wall is of brick and sheet steel. The drums have a magnesia covering with brick laid outside.

The boilers are designed for a working pressure of 200 lb. Half of the boilers are stoker-fired. These are equipped with shaking grates and dump plates. Natural draft only is employed with these boilers.

The boilers furnish superheated steam to the turbines, but saturated steam is taken out of the boilers to run the auxiliaries, as the latter are not equipped to run on superheated steam; except the turbine-driven auxiliaries, such as hot well pumps, which take their steam from the superheated steam mains.

The ashes from each boiler are dumped directly into brick-lined steel hoppers under the boiler, equipped with ash downtakes leading to the basement.

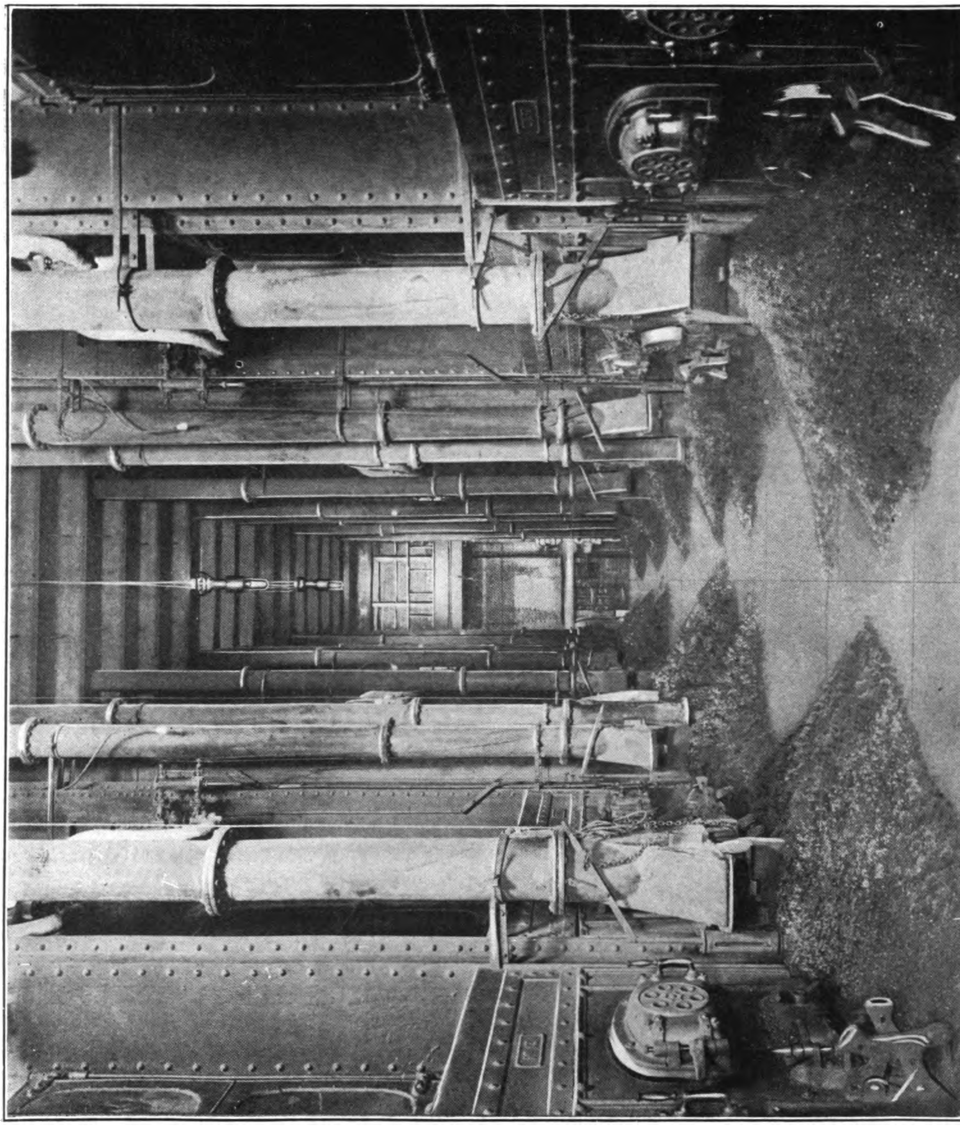


FIG. 68.—Boiler Room, Williamsburg Station.

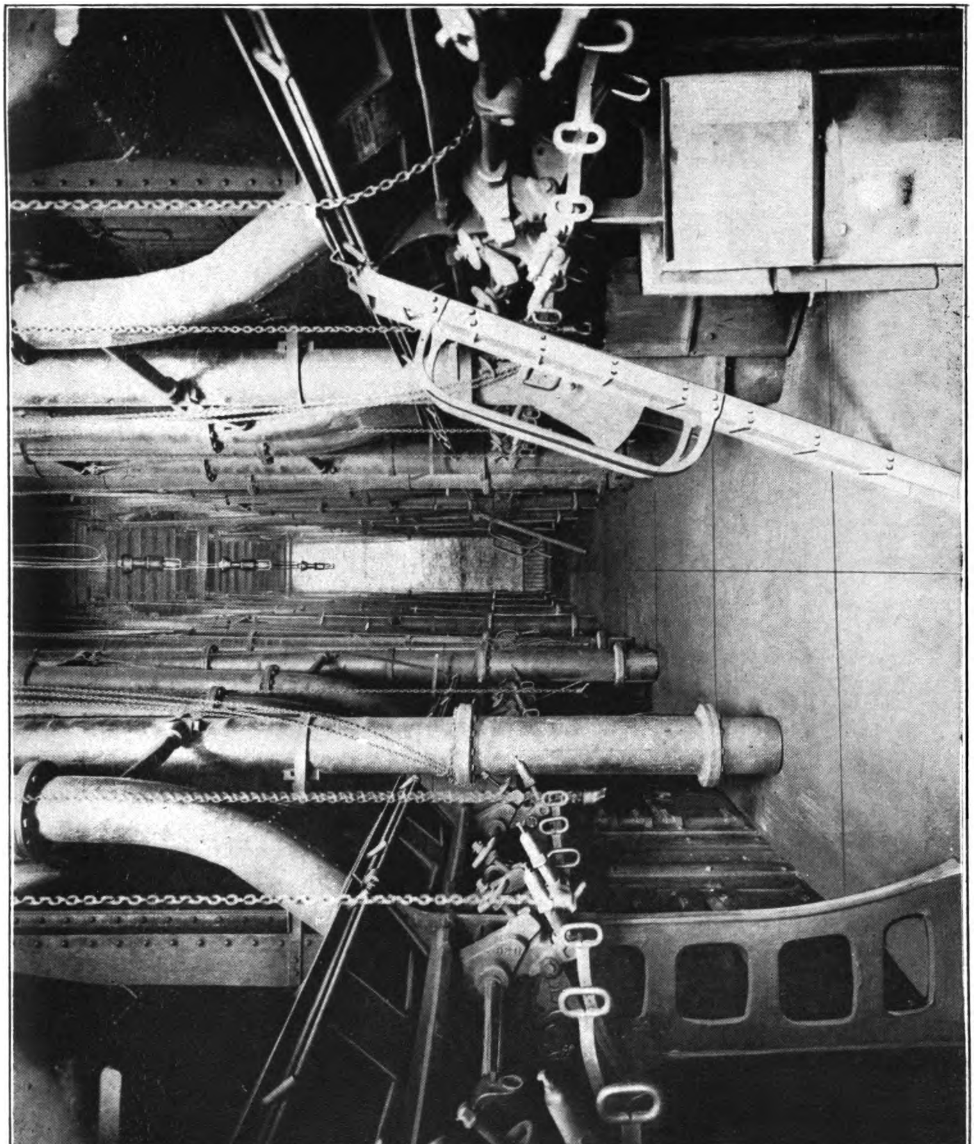


FIG. 69.—Boiler Room, Williamsburg Station.

The air for combustion in the hand-fired boilers is furnished by a forced draft system consisting of twelve 60 by 45-in. multi-vane fans, direct connected to vertical, double-acting, cross compound, 6½ by 11 by 6-in. engines, capable of developing 46 hp at 330 rev. per min.

Each fan delivers air to a steel duct, two fans to a duct, there being six ducts, each duct feeding six boilers. The ducts have a cross sectional area of 25 sq. ft. and extend across the boiler house from blower to blower. The ducts are hung, next to the ash hoppers, under the first and second tier boilers respectively, three ducts to each tier. The fans are regulated by an automatic damper regulator, operating on the rise or fall of the steam pressure and speeding up or slowing down the fan accordingly.

The air is delivered to the furnaces through a special casting so arranged as to give a good distribution of the air for combustion purposes. This casting is bolted to the ash hopper frame, and delivers to a closed ash pit.

As previously stated, there are two systems of steam piping in use at this station, one for high pressure, superheated steam for the main prime movers, and an auxiliary system furnishing the saturated steam for the auxiliaries.

Over each of the 24 boilers a crossover outfit is erected, consisting of three special flanged fittings bolted together and connected to the superheated outlets of each boiler. This is supported on the nozzles, provided on the top of the boiler drums, with flexible connections and having one 8-in. top outlet and a 2½-in. outlet on one supporting nozzle for connection to the saturated steam header. To this top outlet is attached an 8-in. automatic non-return stop and check valve, to which is attached an 8-in. bend connection to the boiler house transverse header, having an 8-in. gate valve operated from the floor below the header. The boiler house transverse header is made up of 8, 10 and 12-in. inside diameter and 15-in. outside diameter extra heavy steel pipe with Van Stone rolled steel joints, and 10, 12 and 14-in. by-pass gate valves supported on, or hung from, the steel work of the building; anchored at the center to provide for free expansion in either direction. The headers from the first and second tier boilers are cross-connected to the 14-in. boiler house longitudinal header which is located about eight feet above the first floor and next to the division wall. From the lower side of this longitudinal header are taken the various turbine leads, nine in all. These leads are provided with the usual separators, strainers, valves and automatic stop valves. The longitudinal header is also connected to the first and second tier boilers of the old Eastern station. All valves not accessible from the floors or walkways are provided with extension stems and floor stands.

Saturated steam for the auxiliaries is obtained as follows: A 2½-in. flanged connection is provided on twelve second-tier and eight first-tier superheated cross-overs, to which twenty-four 2½-in. bent pipe connections are made, leading to 4-in. transverse headers. Each connection is provided with a check valve at the inner end and a gate valve at the outer end. There is also a valve at each end of the 4-in. headers and between each battery of boilers. The 4-in. second-tier headers lead down on each side of the boiler house, joining the first floor headers and extending down to the basement, five inches in size on the operating room side and four inches on the opposite side, where they are again connected by two 4-in. transverse headers. Connections to the feed pumps are made in such a way that any of the pumps may take steam from either or both headers, or from either end of the transverse headers. The blower engine connections are made in the vertical sections of the above mentioned pipes for the second-tier blowers and in the 4-in. transverse headers for the first tier blowers. An 8-in. longitudinal header connecting the 5-in. verticals runs along the division wall in the boiler house basement. This header is provided with the necessary cross connections to connect the exciter engine, the heating apparatus and the auxiliaries in the engine room basement.

All transverse superheated steam headers over the boilers are dripped back directly to the first floor boilers through a gravity return system. The main longitudinal headers are dripped by traps located in the basement below the headers. Drips are run from each of the valves on the 14-in. drops or leads, these drips being connected together by a 1¼-in. header and carried to a trap in the basement. The latter discharges into a 3-in. header, which in turn is connected with the drip tank by a 4-in. line. All traps on the steam separators on the turbines, circulating pump engines, dry vacuum pumps, exciter engines and air compressor, discharge into the 3-in. header. Two drips are provided on the saturated steam system; the piping being pitched so as to drain all water pockets direct to the boilers, except the vertical risers and longitudinal header which are trapped back to the 4-in. header near the drip tank. From the bottom of the drip tank separate valved connections are made to the open heaters, storage tanks and the sewer.

An extensive system of boiler blowoff piping similar to that used in several of the other large stations in the city has been provided.

FEED WATER PIPING.

The condenser returns from all the hot well pumps enter a 12-in. header running along the division wall. From here the condensate enters a dividing box which distributes it and the cold, make-up water to the two pump rooms, through three 10-in. mains. Two of these mains go to pump room number two and one to number one. The condensate can also flow to the tanks in each pump room or to the heaters direct in case either pump or the dividing box is not in use. A six-inch cold water supply loop from the metered service ties directly into the heaters and passes into the dividing box through two six-inch lines to the float chambers and valves, thus providing the necessary make-up water. From the heaters a suction line feeds the pumps in both rooms, a by-pass being provided for the heaters by a tie line connection between the condenser return and the suction line. A 16-in. suction tie line is further provided to permit of pumping from either pump room through either set of heaters and tanks.

Pump room No. 1 contains two horizontal, cylindrical, closed heaters, one right hand and one left hand, each containing 1333 sq. ft. of heating surface, and one horizontal, cylindrical, open heater and purifier 8-in. outside diameter and 15 ft. long. The feed pumps in this pump room consist of three vertical, direct-acting, 19 by 32 by 11½ by 18-in. cross-compound pumps and one horizontal 12 by 26 by 10-in. compound pump.

In pump room No. 2, located under the third section in the boiler house basement, there are two open heaters of the same size as that in pump room No. 1 and four 8-in. five-stage turbine pumps driven by steam turbines.

The pumps deliver to a 10-in. header in each pump room, this header dividing into two 8-in. branches to the 6-in. ring headers, one for each tier of boilers. Six-inch tie lines from each ring header extended across each row of boilers, with 3-in. drops supplying the feed lines to each boiler through a check valve and feed valve.

Thus there is a complete ring header for each tier of boilers and a complete ring for each row of boilers that can be fed from either pump room through the necessary by-passes.

Economizers are provided in the first section of the boiler house, consisting of eight units, four in the upper tier of boilers and four in the lower. These are staggered tube economizers, each unit containing 692 cu. ft. of water and 8,077 sq. ft. of heating surface. The tube scrapers are operated by four 5 hp. motors.

THE TURBINES.

The power generating apparatus for this station consists of: Four 7500-kw. horizontal single flow turbines and five 10,000-kw. horizontal double flow turbines.

The foundations for turbines Nos. 1, 2, 3 and 4 are of reinforced concrete. The foundations for the remainder of the turbines, Nos. 5, 6, 7, 8 and 9, consist of eight steel columns, built up from two 12-in. 20½-lb. channels covered with two 16 by ⅜-in. steel plates, supporting four main girders, made up from angles, plate webbs and cover plates, these girders in turn supporting seventeen 18-in., 70-lb. I-beams as cross supports for the turbine and generator.

The turbines Nos. 1 to 4, inclusive, are of the type known as multiple expansion, parallel flow and adapted for driving direct connected generators, giving 3,000 alternations per minute at 750 rev. per min. The turbine with its generator is mounted upon a continuous bedplate, provided with suitable supports for the generator, bearings and turbine.

These turbo-generators develop 7,500 kw. when operating at 750 rev. per min., with steam pressure at the throttle of 175 lb. gauge and a vacuum of 28 in., referred to a thirty-inch barometer.

The turbine is also provided with a by-pass valve by means of which 50 per cent overload may be developed or full load developed when operating non-condensing.

Governing and regulation of these turbines is obtained by the usual balanced poppet valve and governor.

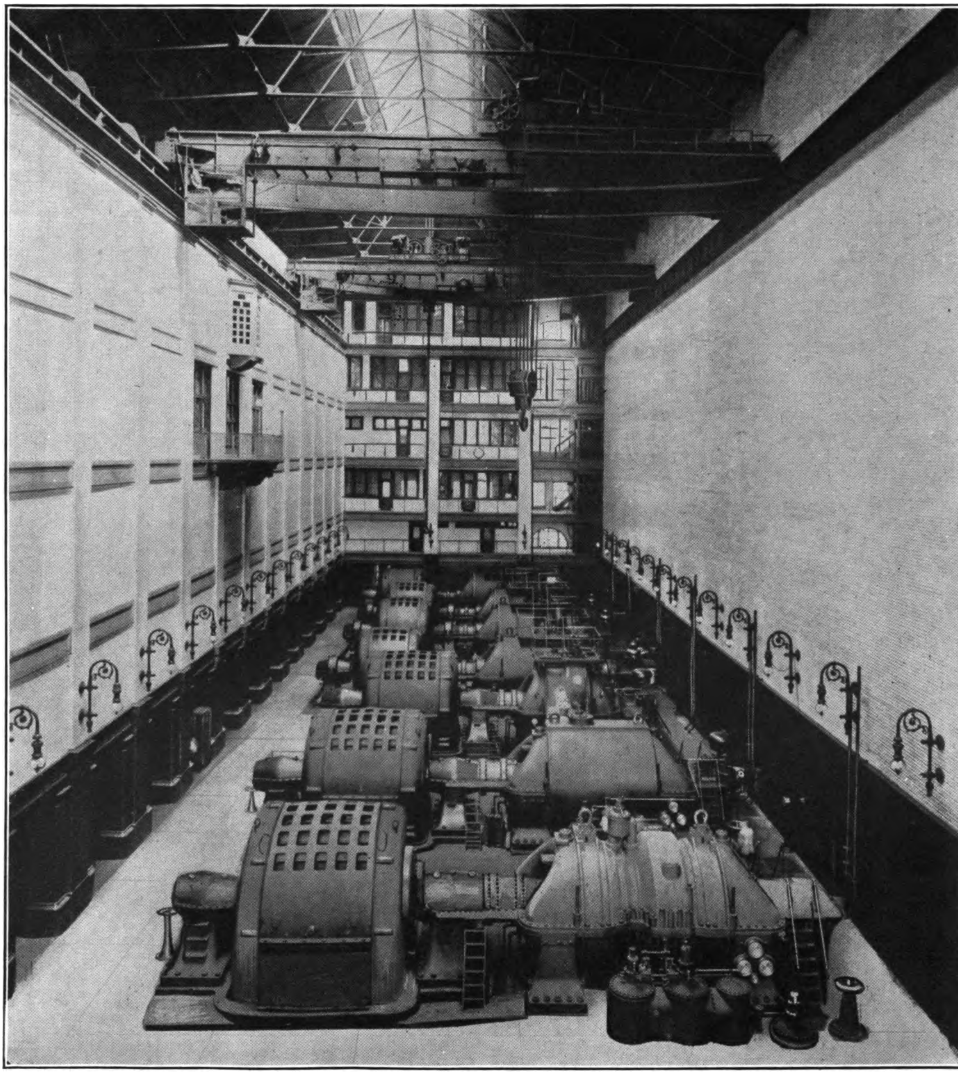


Fig. 70.—Operating Room, Williamsburg Station.

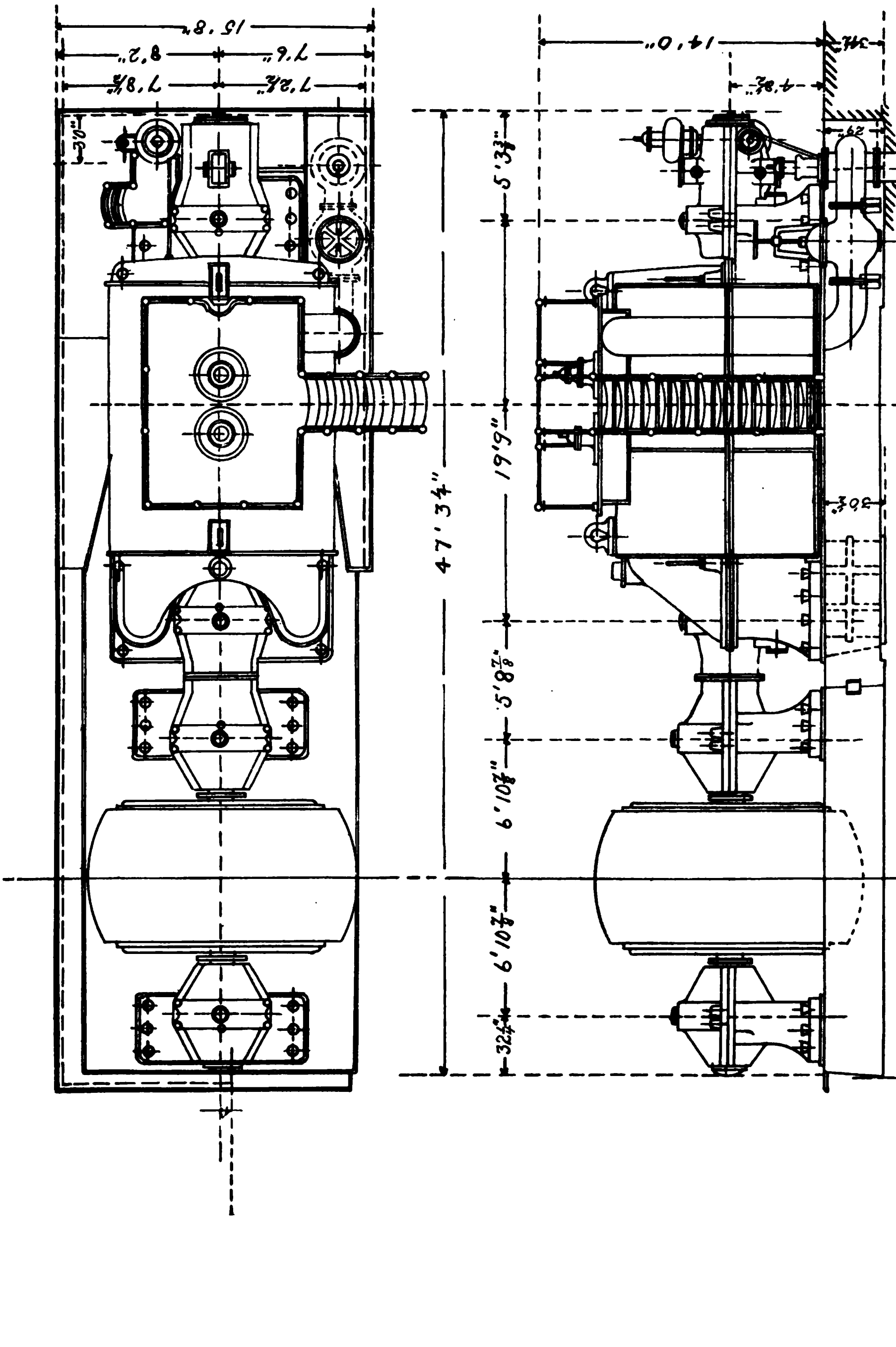


Fig. 71.—Westinghouse Turbo-Generator Set, Williamsburg Station.

The balance of the turbines, Nos. 5, 6, 7, 8 and 9, are of the multiple expansion, double flow type, of 10,000 kw. normal capacity. Steam enters the cylinder at the center and flows in opposite directions, thereby doing away with the usual balancing pistons and dummies, making a much more powerful turbine in a given space, and eliminating the undesirable end thrusts. These units operate between 175 lb. gauge pressure with 150 deg. fahr. superheat, and a vacuum in the exhaust nozzle of 28 in. The governing devices, safety stop valve, strainers and throttles are all similar to the other turbines.

THE AUXILIARIES.

Turbines Nos. 1 and 2 are equipped with surface condensers, containing 22,000 and 25,000 sq. ft. of cooling surface respectively. The hot well pumps are vertical shaft, two-stage 5-in. centrifugal, motor-driven pumps. The dry vacuum pumps are horizontal, straight line rotative, steam-operated pumps, 10 by 26 by 18-in. for No. 1, and 12 by 30 by 24-in. for No. 2 turbine, running at 55 rev. per min. The circulating pumps are horizontal, 30-in. volute pumps, direct driven by 12 by 20 by 14-in. vertical compound engines developing 190 hp. at 275 rev. per min.

Turbines Nos. 3 and 4 have surface condensers containing 25,000 sq. ft. of cooling surface. The hot well pumps are 5-in. volute, single-stage pumps, driven by 25-hp. motors. The dry vacuum pumps are horizontal, straight line rotative, steam-operated pumps, 10 by 24 and 24 by 24 in. The circulating pumps are steam turbine pumps, 150 hp. at 680 rev. per min.

The auxiliaries for turbines Nos. 5, 6, 7, 8 and 9 are all alike. The condensers are of the two-pass dry tube type, with 20,000 sq. ft. of cooling surface. The hot well pumps are 5-in. single stage volute pumps, driven by steam turbines running at bout 1,650 rev. per min. The air from these condensers is handled by horizontal, straight line, single air cylinder, steam operated pumps 12 by 30 by 14 in. Circulating water is pumped by means of 30-in. horizontal, volute pumps operated by 12 by 12-in. steam engines.

Compressed air for various uses throughout the station is obtained from two air compressors located in the compressor room in the basement of the boiler house, this room being adjacent to the store room. One compressor, a 10 by 14 and 10 by 14-in. duplex machine, with steam at 80 lb. pressure and running at

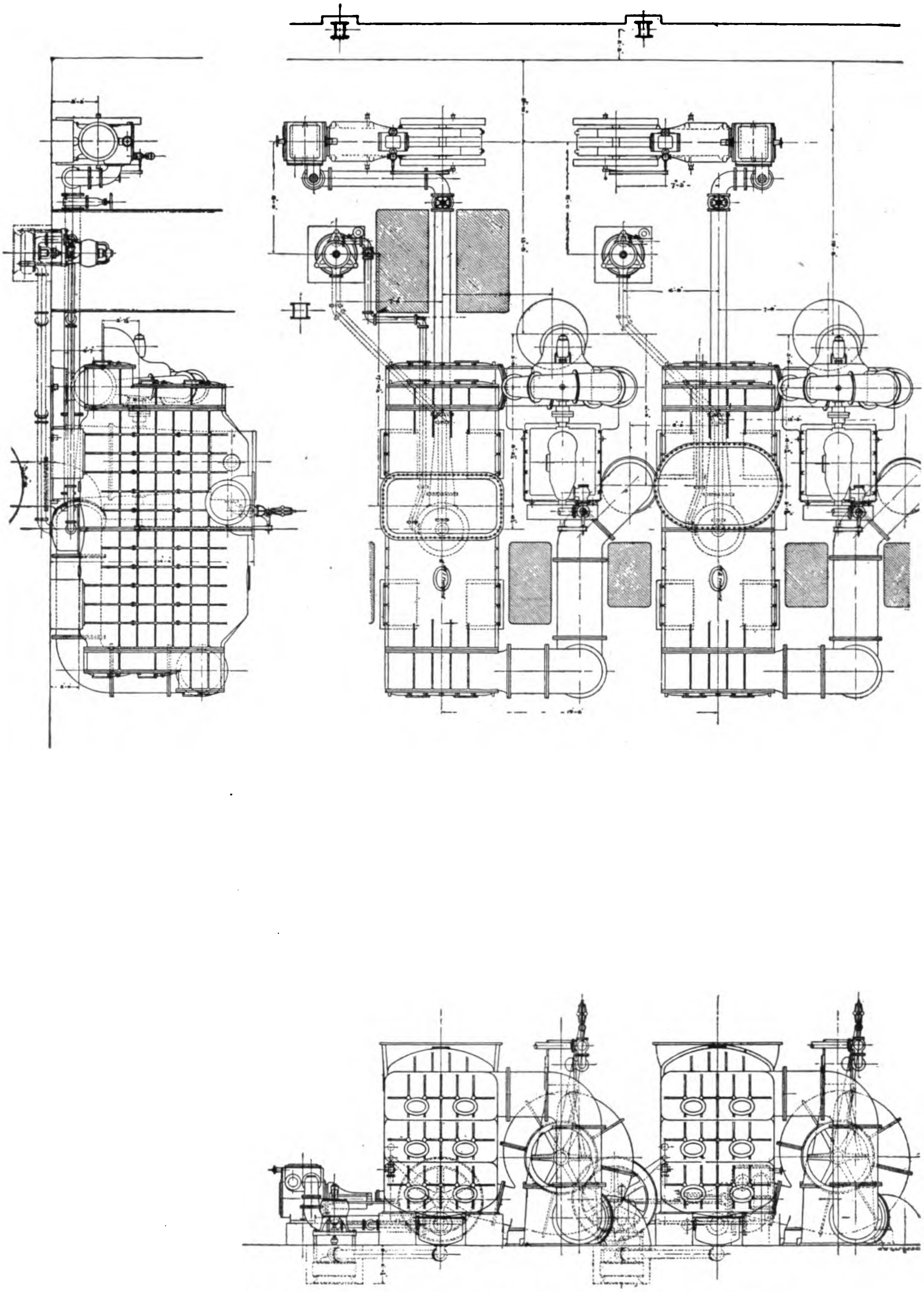


Fig. 72.—Worthington Condensing Outfit, Williamsburg Station.

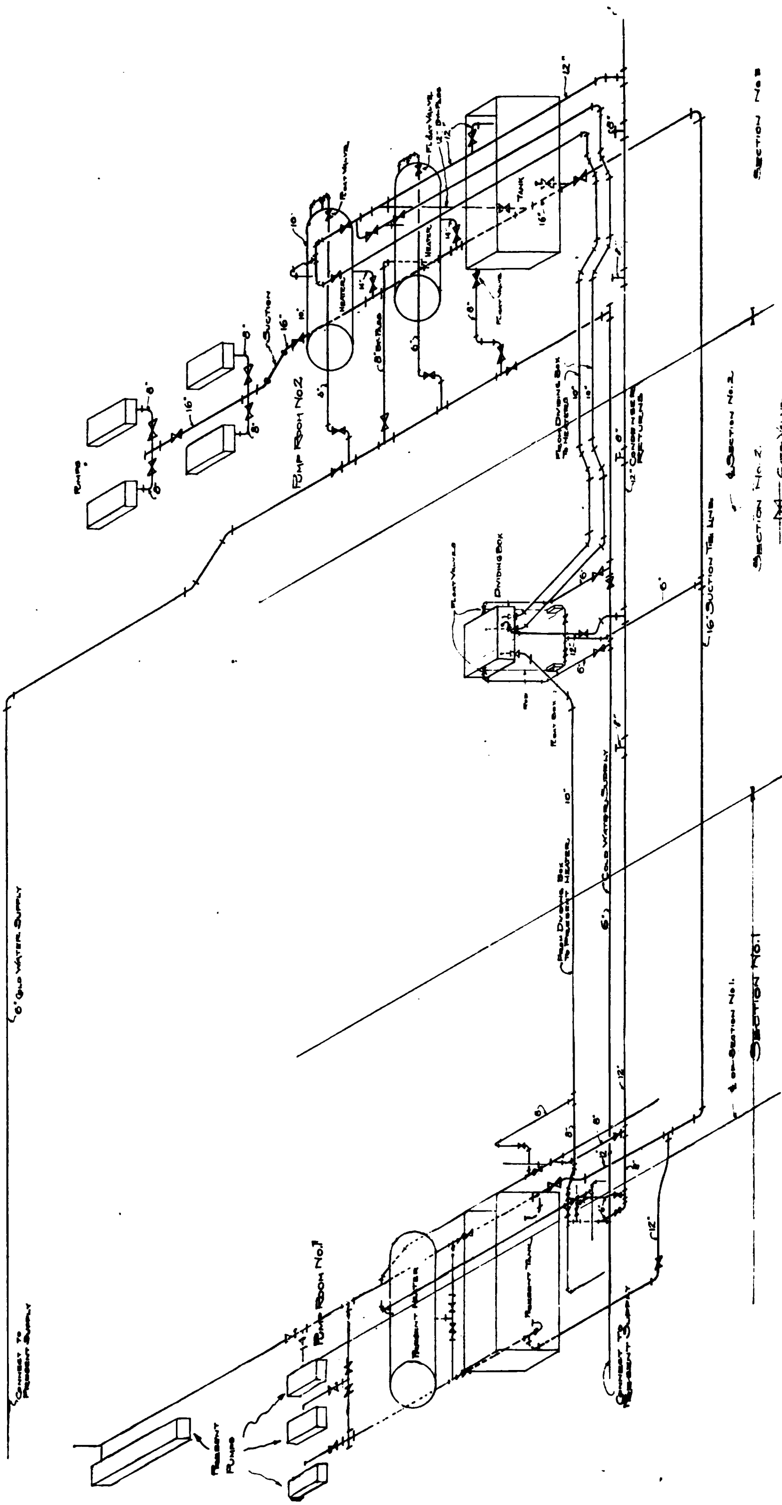


Fig. 73.—Suction Condenser Return and Cold Water Supply, Williamsburg Station.

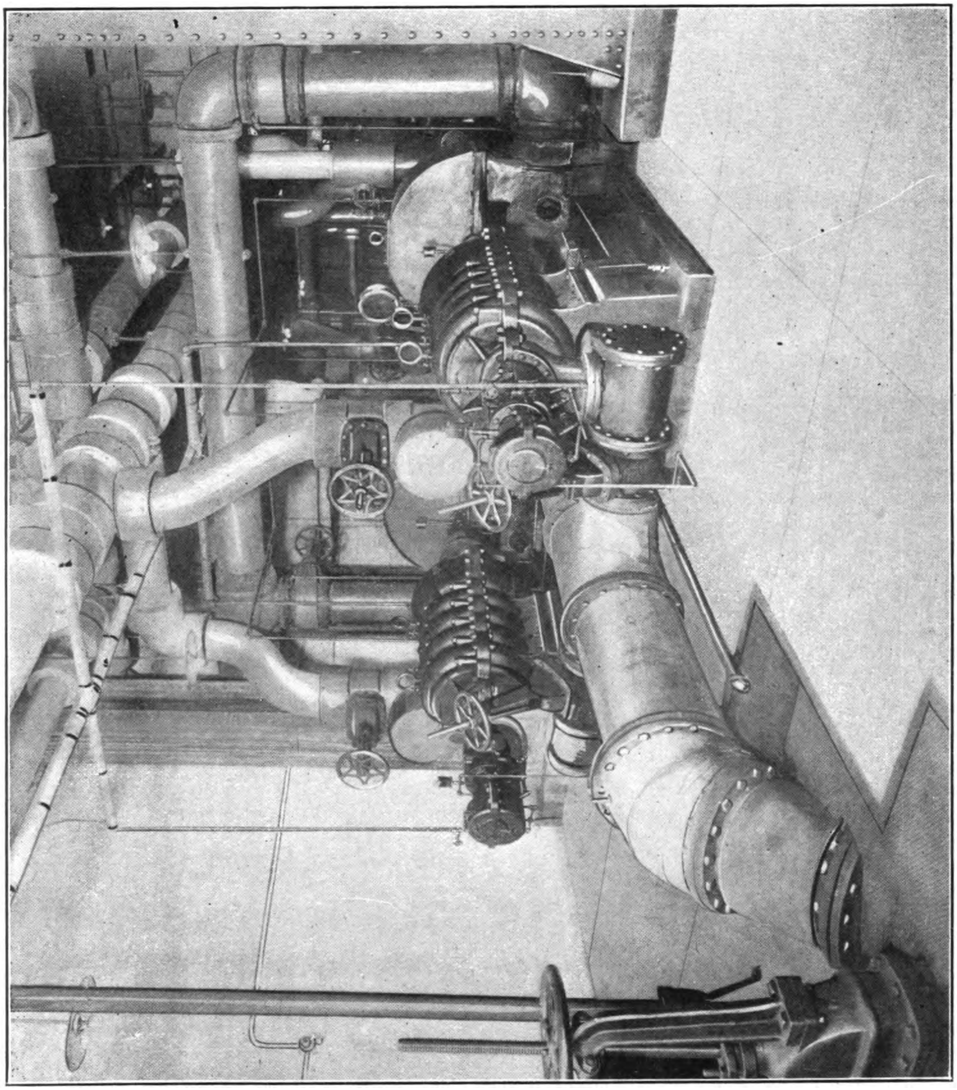


FIG. 74.—Pump Room, Williamsburg Station.

130 rev. per min. delivers 644 cu. ft. of air at 100 lb. pressure. The other compressor is a 13 by 20 and 19 by 12 by 14-in. compound steam and air cylinder machine.

MAIN ATMOSPHERIC EXHAUST PIPING.

A 30-in. back pressure valve is installed at the exhaust outlet of each turbine, this valve being connected to the vertical exhaust riser in the boiler house. Near the connections to this vertical riser a 30-in. gate valve is provided on either side. The bottom casting of the riser is fitted to receive the exhaust from the auxiliaries. The vertical riser leads from the boiler house basement to a point near the roof of the operating room, through the wall to an exhaust head, this lead being drained back direct to the leader.

The exhaust from the groups of turbine auxiliaries is led into a 12-in. wrought iron pipe to a 14-in. wrought iron longitudinal header in the boiler house basement. Each group is provided with a by-pass connection to the free exhaust, with connection to the dry vacuum pump discharge. From this header 18-in. wrought iron transverse pipes lead to the open heaters. Ten-inch connections are also provided for the closed heaters, drip pockets being provided in all these lines. A vapor pipe is led from each heater to the free exhaust main. A 10-in. cross connection is made between the exhaust supply and the free exhaust with a 10-in. back pressure valve for relieving undue pressure on any part of the system. Exhausts from the boiler feed pumps and all engines driving blowers and auxiliary machinery on the south side of the building are connected through a 10-in. main to the 18-in. transverse header just back of its branch to the open heater. Similarly, the exhausts on the north side are collected together and run direct to the 18-in. mains. The operation of the system is such that either or all heaters may be automatically supplied with exhaust or live steam or both. Also it is provided that all the exhaust may be first passed through the open heaters and any portion remaining uncondensed afterward used in the closed heaters. Both styles of heaters are equipped with live steam connections with automatic high pressure reducing valves, properly by-passed. From tees on the suction of the dry vacuum pumps a 3-in. line is run to the highest point in the corresponding condenser circulating pipes, provided with valves at each end, there being similar valves at all auxiliary connections. Safety valves are provided for the closed heaters.

OILING SYSTEM.

A receiving tank is located in the operating room basement, one end of which is connected to a 4-in. suction header connecting the two 7½ by 7½ by 6-in. oil pumps in the western end of the operating room basement under the mezzanines. From these pumps 3-in. connections are made to the storage tanks on the top mezzanine, these tanks being connected to the central oil header and to the independent oil header, both of which are installed on the operating room side of the division wall. Two-in. by-passed connections are made between the central header and the turbines, also 1¼-in. connections between the independent header and the turbines. From the drain outlet on the turbines, 2-in. connections are made to the 8-in. return header. This header returns the oil to either or both oil filters, located near the pumps under the mezzanine. The filter tanks are also connected with the pump suction line. A 3-in. overflow pipe, connected to both storage tanks, discharges into the filter tanks in the basement. Water connections for purposes of cleaning the system are provided. The storage tanks have a capacity of 4,500 gal. each.

A complete ash wetting down system, house supply and fire service system has been installed in the building.

ELECTRICAL APPARATUS.

The electrical generating apparatus of this station consists of four 7500-kw., four-pole, rotating field, three-phase, 25-cycle generators, 6600 volts, at 750 rev. per min. direct connected to turbines Nos. 1, 2, 3 and 4; and five 10,000-kw., four-pole, rotating field, three-phase, 25-cycle generators, direct connected to turbines Nos. 5, 6, 7, 8 and 9. These last five generators also generate current at 6600 volts pressure when running at 750 rev. per min.

From each generator armature the three 800,000-cir. mil. high tension cables are lead covered and run through vitrified ducts in the columns up to the generator oil switches on the fourth mezzanine floor. On this floor are also located the group switches, the path of the current being from the generator oil switches to the generator bus-bars and from the latter to the group switches and feeder bus-bars. These are located in the bus-bar compartments

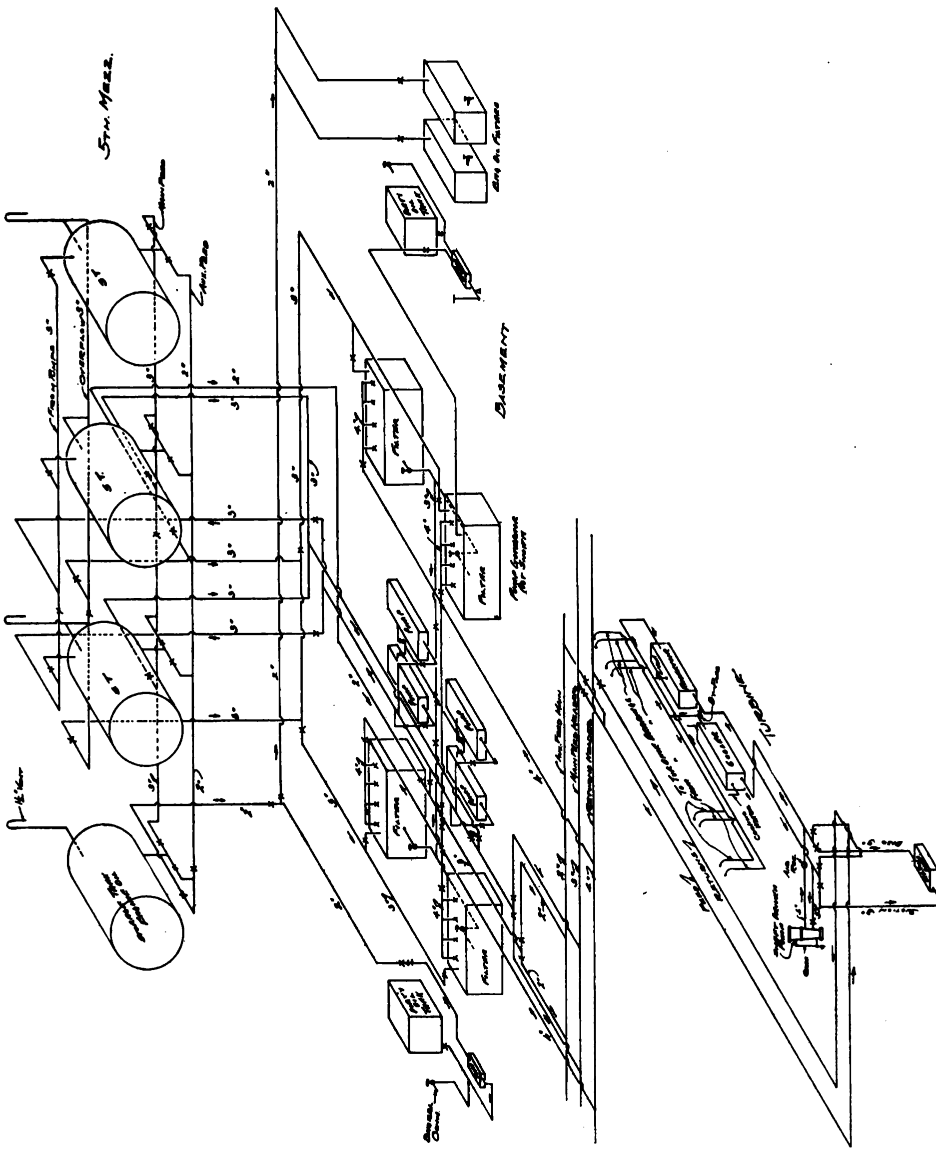


Fig. 75.—Oiling System, Williamsburg Station.

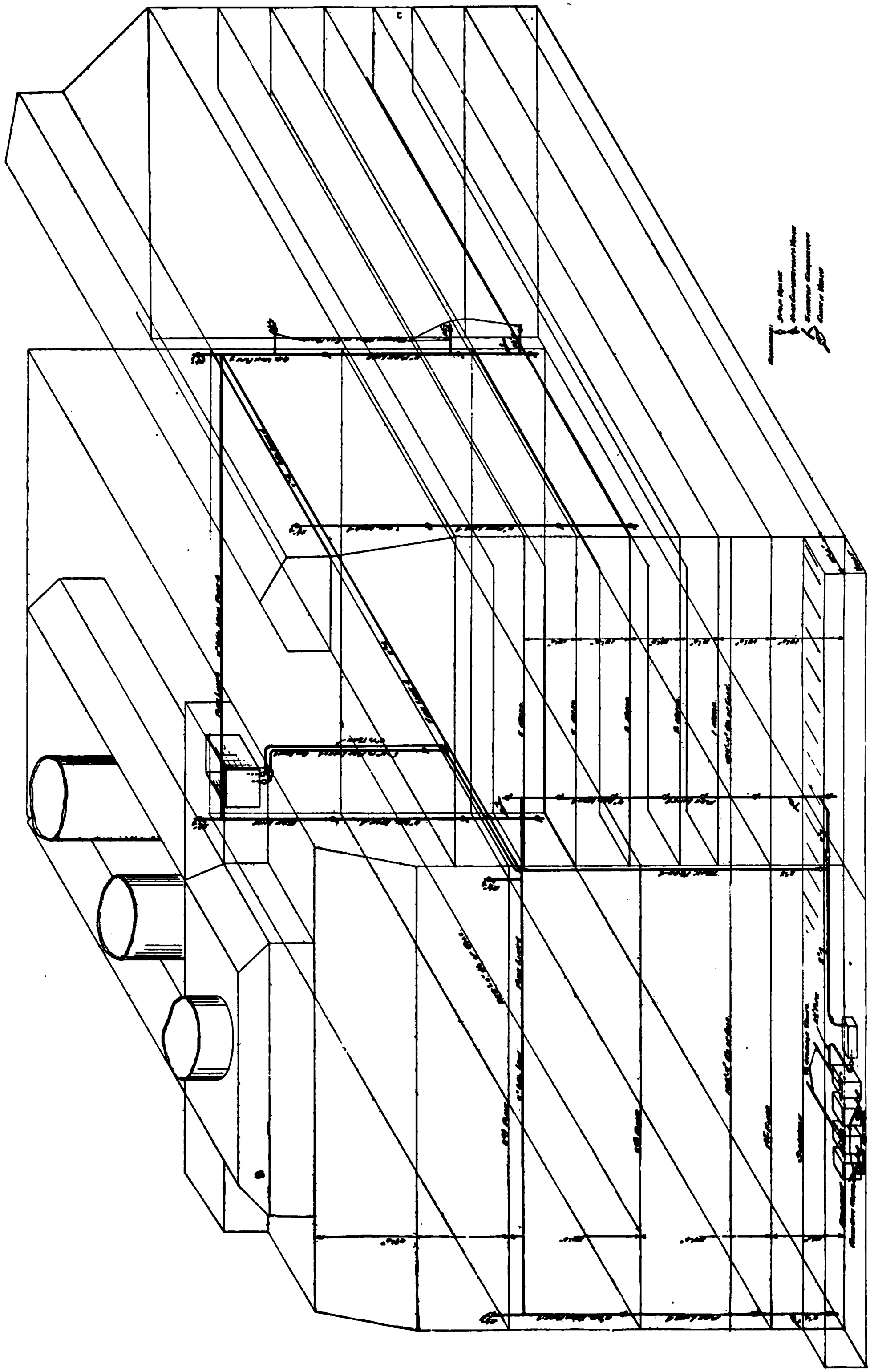


FIG. 76.—Fire Lines, Williamsburg Station.

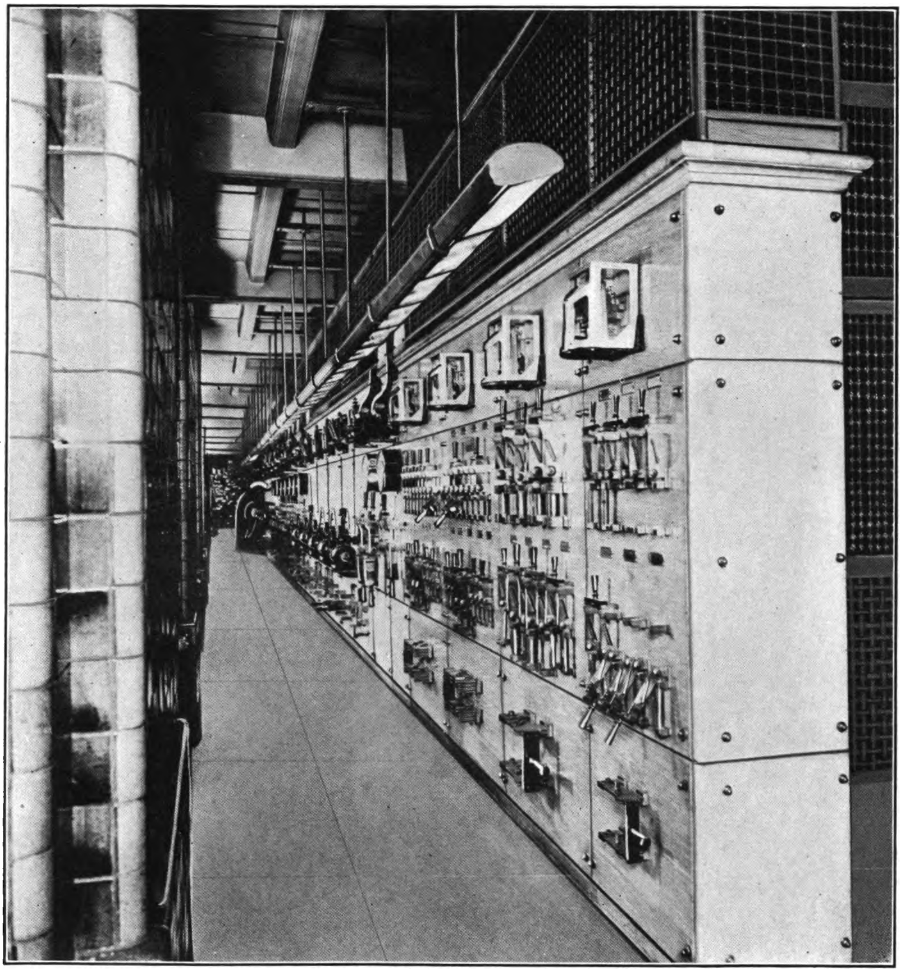


Fig. 77.—Low-Tension Switchboard, Williamsburg Station.

on the third mezzanine, whence the cables lead down to the feeder oil switches on the second mezzanine, thence to the cable end bells and cable vaults and racks, located on the first mezzanine.

Arrangement has been made to feed direct from the generator switch to the feeder bus in case of accident to the generator bus by means of 1200-amp. knife switches located in fire brick compartments in the cable ducts on the third mezzanine.

The generator bus is divided up into sections, one section having three generators tied in, the other sections having two generators each. Each generator section is connected to its sections of feeder bus-bars, controlled by the group of switches. The sections of generator bus-bars can be tied in by means of copper laminated tie buses, set on vertical studs.

The generator bus is made up of five 3 by ⅛-in. copper laminations, the feeder bus of two 3 by ⅛-in. copper laminations.

All the switches are of the remote control type and are operated from the control board located on the third mezzanine floor near the center of the building.

The control cables connect with the various switches and transformers throughout the galleries, through control pipe-runs laid in the floors and walls of the electrical galleries.

The generator control stand, as previously mentioned, is located in the semicircular bay of the third mezzanine floor. This is of the modern flat desk type and contains twelve control panels, one for each generator, leaving three panels blank. Each panel contains the usual instruments for this service. These instruments are grouped in the most convenient form on the top, front and rear of the stand.

In front of the generator control board is the semicircular high-tension board made up of 16 feeder panels. The front of the board contains the usual phase ammeters, power factor indicator, indicating lamps and group switch controllers. On the rear of the board are the wattmeters, relays and calibrating switches.

On the extreme eastern end of the high-tension board is the special high-tension feeder panel. The instruments on this board are for the 300-kw., motor-generator, exciters Nos. 1 and 2, bus tie control and test set.

The transformers for the high-tension system are located in the basement under the electrical galleries.

The direct current switchboard is situated on the main floor of the electrical galleries. It has provision for 44 panels. On these panels are located instruments for station light and power board, light and power supply, the generator field, the battery and the exciters.

From the 575-volt railway bus in the old station, two sets of 1,200,000-cir. mil. cables lead to 1200-amp. d.p.s.t. switches on the power and arc lamp boards respectively. The remainder of the power and light panels are used for 125-volt incandescent lamps.

Adjacent to the station power and light board are the panels for the control of the supply of light and power. Then come the panels containing the motor operated rheostats for the generator fields, these motors being controlled from the generator control stand. The battery panels contain the necessary instruments for the control of the battery and the booster. Adjoining the battery panels are the panels with the instruments and regulators for the motor generator sets.

The storage battery is located on the fifth mezzanine floor and consists of 60 type G cells, of 51 plates. This battery has a capacity of 2000 amp-hr. at a one hour rate.

There are six sets of exciters, all located on the main floor of the electrical galleries (see general plan). One of the sets is driven by a 15 by 27 by 16-in. single-acting, compound engine. It has a capacity of 150 kw. when running at 225 rev. per min. and with a pressure of 125 volts. Thus in case of any electrical tie up in the system, the steam exciter would still be operative.

To the west of this exciter are motor-generator sets Nos. 2 and 3. These are of 150 kw. capacity at 125 volts and are direct connected to 220-hp., 429-volt motors.

Still further to the west of these two sets and partially behind the direct current board is a 300-kw. exciter, driven by a 430-hp., 429-volt motor.

Motor-generators Nos. 5 and 6 are directly in line with turbine No. 5 and behind the direct current switchboard. These sets are of the same size and capacity as exciter sets Nos. 2 and 3.

HIGH-TENSION FEEDER TESTING SET.

From the high-tension buses connections are run to the test switch and to the bus transformer, located on the first mezzanine.

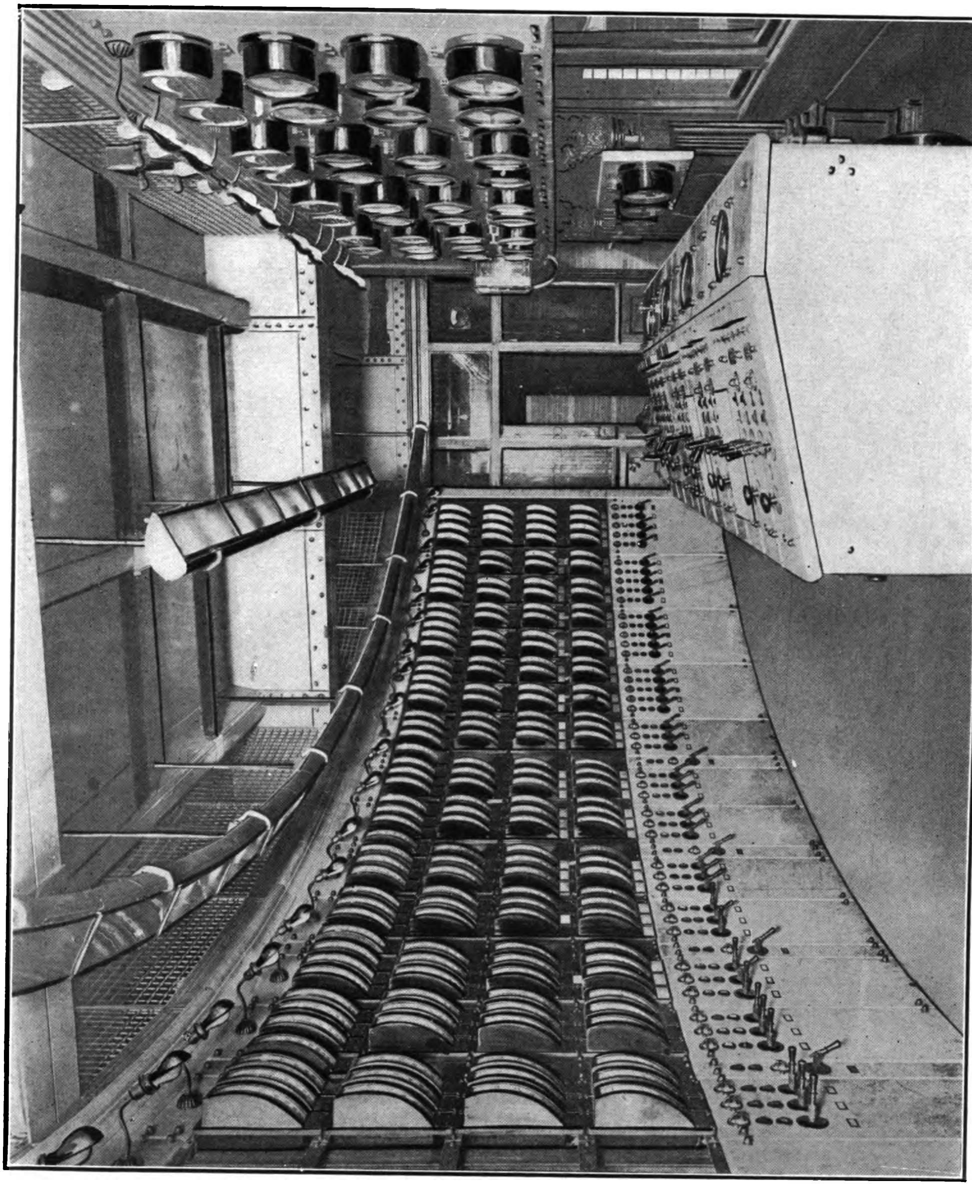


Fig. 78.—High-Tension Control Board, Williamsburg Station.

The connections from the transformer pass through a cable run to the induction regulator located in the test room. From the induction regulator connection is made through K switches to a line transformer and thence to the oil switches located in the fire-brick compartments at the rear of the test room. From here the cables pass to the selector switches, which are in a separate compartment, and then through a cable runway to the compartment for the flexible test cables (shown on the plan). The operator can by this arrangement take the test cables and test any one of the feeder switches located in that section.

THE TURBINE SIGNAL AND GOVERNOR CONTROL APPARATUS.

From the generator control stand on the third mezzanine, cables, composed of seven No. 12 and four No. 7 wires, lead down through a pipe cable runway to the respective generators. The d.p.d.t. switch on the control stand operates automatic limit switches for the governor control motor. This permits the operator to have complete control of the speed of the turbine when synchronizing. At the same time the electrical operator has at his hand three signal switches and signal lamps, which operate similar lamps, marked **SHUT DOWN, O.K.** and **FULL SPEED,** in the floor signal stands at each turbine, a push switch on this stand operates the signal lamps on the generator control stand.

An electric annunciator on the curtain wall, located between the fourth and fifth mezzanines, permits the operator at the generator control board to signal the number of the turbine he wishes to put into service. This is done by means of switches operating electric lamps behind glass numbers on the annunciator board.

There is thus a complete and separate annunciator mechanism, signal apparatus and governor control for each and every unit.

CENTRAL STATION
OF THE
CITIZENS' LIGHT & POWER COMPANY
ROCHESTER, N. Y.

THE CENTRAL STATION OF THE CITIZENS' LIGHT & POWER COMPANY, ROCHESTER, N. Y.

GENERAL.

The Citizens' Light & Power Company, which commenced operation in the fall of 1892, located their plant on the west bank of the Genesee River at Brown's Race and Factory Street, near the center of the city. Brown's Race is an artificial waterway, 36 ft. wide by 7 ft. deep, running from the Genesee River at Central Avenue to Brown Street, where the overflow returns to the river. The plant was built on the river bank below this race, which gives a head of 93 ft. on the wheels.

The power plant was a combination one, using both water and steam power. The steam plant was a very necessary adjunct, as the Genesee water supply is a somewhat uncertain quantity, the company being obliged to carry a full head of steam, as they could take no chances of having their business interrupted. In summer the supply of water would be small indeed, and in the winter it is full of ice and at all times full of rubbish, which the river collects on its way through the city.

Immediately to the south of the old station is a piece of property about 200 ft. long by 96 ft. wide, which was occupied in part by an old factory. This property was acquired and the old buildings were torn down, revealing the solid rock extending from the race on the west, at an elevation of about 99 ft. above low water, to a factory building on the eastern side, about 23 or 24 ft. above low water. On the south side of the new property is located a large factory building, so that in excavating for the new station it was necessary to channel the rock at a distance from the property line of about 2 ft. in order to preserve the adjoining foundations from injury. This left a width of about 93 ft. on which the new station could be built. After a number of studies, it was decided that the engine house should be erected on the end of the lot toward the river, with the boiler house on a step of such height that the coal for use in the station might be driven in the ordinary coal carts from Race Street on to the roof and dumped through holes into a coal pocket, situated above the boilers. The race itself runs in a general northwesterly and

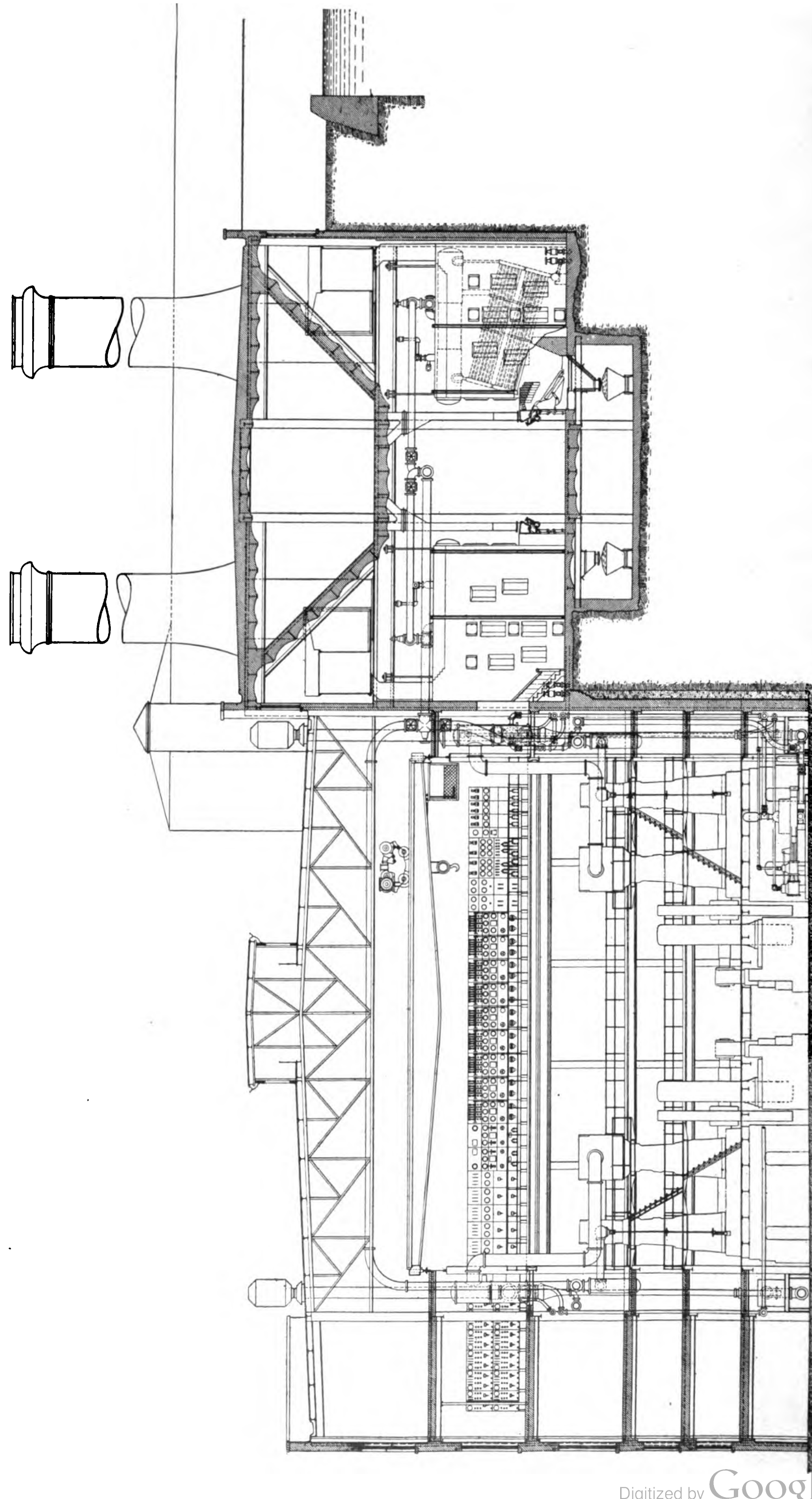


FIG. 79.—Cross Section, Citizens' Light & Power Co., Rochester.

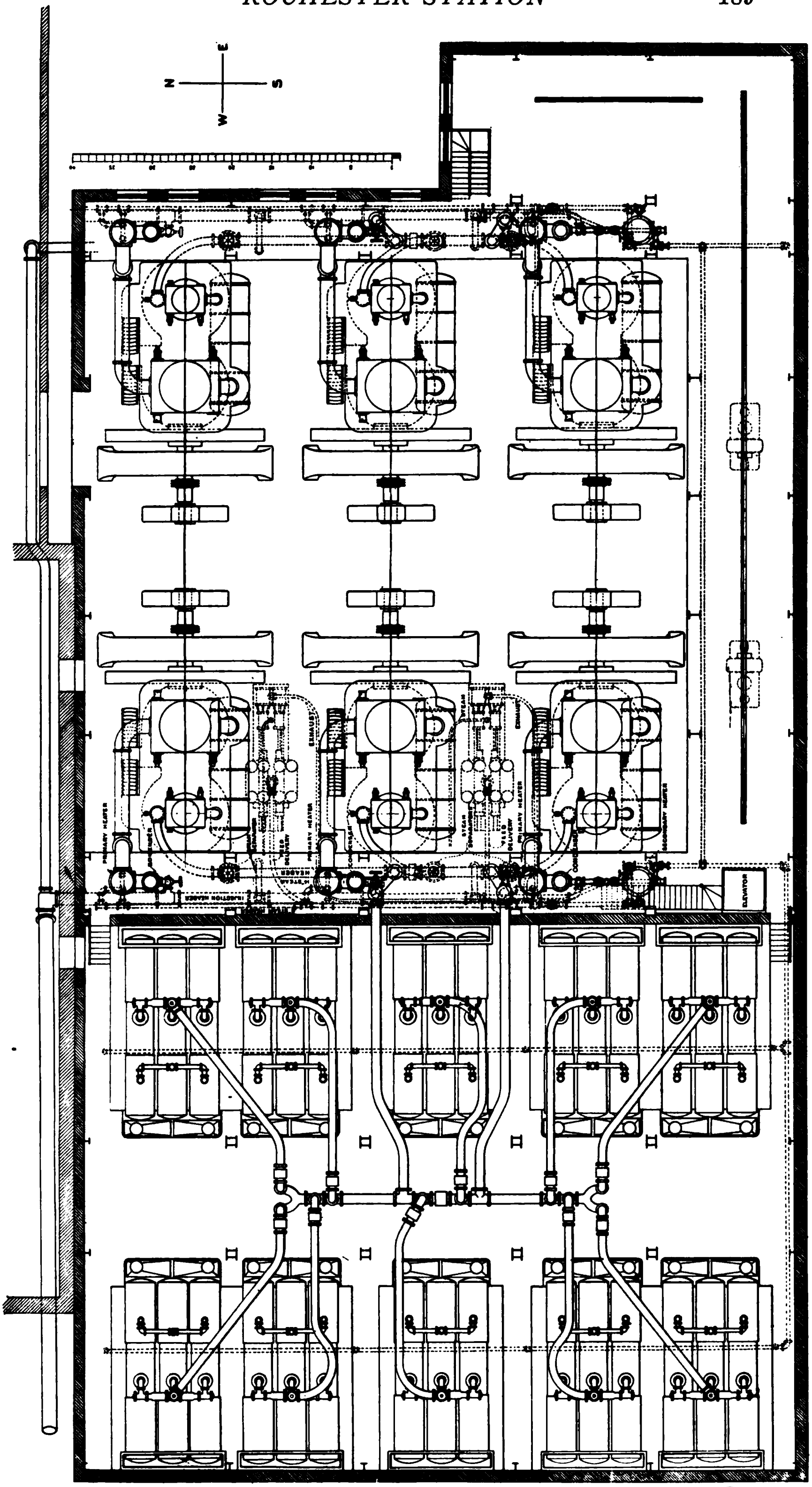


FIG. 80.—General Plan, Citizens' Light & Power Co., Rochester.

southeasterly direction, 43 ft. from the building along the north side of the lot, and 10 ft. from the building at the south side. The rock on his line was channeled down to a grade of about 58 ft. for the main floor of the boiler house. The boiler house basement is only of sufficient width to take in the two ash hoppers, and the center aisle was channeled down 10 ft. deeper, while a step of 30 ft. was made to take the west wall of the engine room. The solid rock was leveled up with concrete to about the grade of various floors, as shown on the cross-section.

The engine room has mezzanine floors on either side, which support steam piping, condensers and other auxiliary apparatus, leaving the engine room a clear space, devoted to engines only.

The engine house proper is approximately 76 ft. square inside of the columns and is spanned by an electric traveling crane of 35 tons capacity.

The engines themselves are set in two lines, running north and south, with the shafts running east and west, 25 ft. 9 in. from center to center.

The generators are outboard of the engine, occupying the center of the engine room, leaving an aisle 10 ft. wide between the two lines of generators.

On the east and west sides of the engine room the four mezzanine floors are placed, the two lowest being at the level of the engine platforms. The third mezzanine is used for the support of the condensers and heaters, and the fourth mezzanine, 46 ft. 8 in. above the engine room floor, has at its outer edge the supports for the crane runway. Eight feet above this mezzanine floor extends the lower chord of the engine room trusses, which span the engine room from wall to wall 90 ft. in the clear. A monitor, to admit light and afford ventilation for the engine room, extends down the center of the roof, in a north and south direction, above the trusses.

At the south side of the engine room are three electrical galleries. In the southeast corner of the engine room an addition extending up the full height of the building, 18 ft. 6 in. by 43 ft., is also used for switchboard space.

The boiler house is 89 ft. 4 in. by 68 ft. 7 in. in the clear, and contains ten 650-hp. Babcock and Wilcox type boilers. These boilers are set in four batteries of two boilers each, occupying the four corners of the boiler house, with a single boiler set in the center of either side occupying the space immediately under the stacks. The boilers are set with no space behind them, cleaning doors being provided at the sides instead of in the back.

The uptakes from the boilers occupy the full width of the boiler, the back wall being protected by a cast-iron plate. These uptakes go directly upward into the bottom of a flue, which extends the full length of the boiler house on each side, discharging into the bottom of the stacks near the center of the station. The coal pocket, having a capacity of 1,300 tons, occupies the second story of the boiler house.

The roof over the boiler house is made sufficiently strong to support large coal wagons, which deliver fuel for use in this station, the roof being nearly level with the street. The foundations for the stacks are also in this roof, and consist of heavy beams and girders. The stacks themselves are 10 ft. 3 in. in diameter, 178 ft. above the grates and 130 ft. above the base of the stack foundation girders. They are lined for 20 ft. above the base with 4½-in. fire brick and are two in number, standing on the east and west center line of the station, about 41 ft. from center to center. Each stack is made up of 30 ft. of ⅜-in. plate, 50 ft. of 5/16-in. plate and the uppermost 50 ft. of ¼-in. plate. Near the northwest corner of the boiler house roof, a bridge on a grade of 5 per cent. connects the roof with Brown's Race, forming a runway over which the coal carts pass. From a point on the roof of the engine house, near the center of the south wall, a cable runway is built above the roof, following the south line of the building and bridging Brown's Race to a cable tower on the west side of the race. Through this cable runway all the electrical cables of the station are taken to the underground conduits.

The outside building lines in many cases are only 6 or 8 in. away from the rock, which often extends as much as 40 ft. above the base of the wall, and provision has been made for the waterproofing of the outside of the wall and the proper draining of the space enclosed between the rock and the waterproofing. The walls themselves are built of the best hard burned red brick, of selected quality and color.

All floors, with the exception of the main floor of the engine room, are of expanded metal construction, faced with a 2-in. coat of granolithic finish. The engine room floor itself is made of cast-iron checker plates ¾ in. thick and properly ribbed.

The roof of the engine room consists of terra cotta roofing tile, laid between T-irons, covered with a slag roof. The roof over the boiler house consists of expanded metal arches covered with composition roofing and vitrified paving brick, laid on edge, in roofing cement.

As the station has no frontage on the street, the main door is situated upon the roof, near the partition wall at the south side of the station, and stairs and an elevator connect this entrance with various floors of the engine and boiler rooms.

The engine and generator foundations are of monolithic concrete molded in wooden forms. Besides carrying the engines, these foundations support the floor beams for the main floor.

The boiler fronts, the automatic stokers, the concrete ash-hoppers and part of the side walls of the boilers are supported by the main boiler-house floor, but the boiler drums and tube sections are hung from pairs of 15-in. I-beams, which frame into the horizontal coal pocket girders.

The stacks are supported from the boiler-house roof by a system of heavy girders and beams, as shown in Fig. 3. Each stack is anchored to the girders by eight bolts 1¾ in. in diameter, with ends upset to 2¼ in.

THE BOILERS.

The boilers are of the standard double-deck type, containing twenty-one sections of fourteen 4-in. tubes, 18 ft. long, and three 42-in. drums about 22 ft. long. They have a heating surface of 6386 sq. ft. each, and are rated at 650 hp. each on a 30-lb. basis, but are guaranteed to run continuously at a 50-per cent. overload. The boilers are designed for a working pressure of 225 lb. These boilers are equipped with Acme automatic stokers, which are especially arranged for the smokeless burning of soft coal. The stokers have a large grate surface, and are designed to meet severe conditions.

The concrete ash hoppers are hung from the steel structure immediately below the stokers and discharge into a trough, where a stream of water carries the ashes down in a chute to the flat below the station.

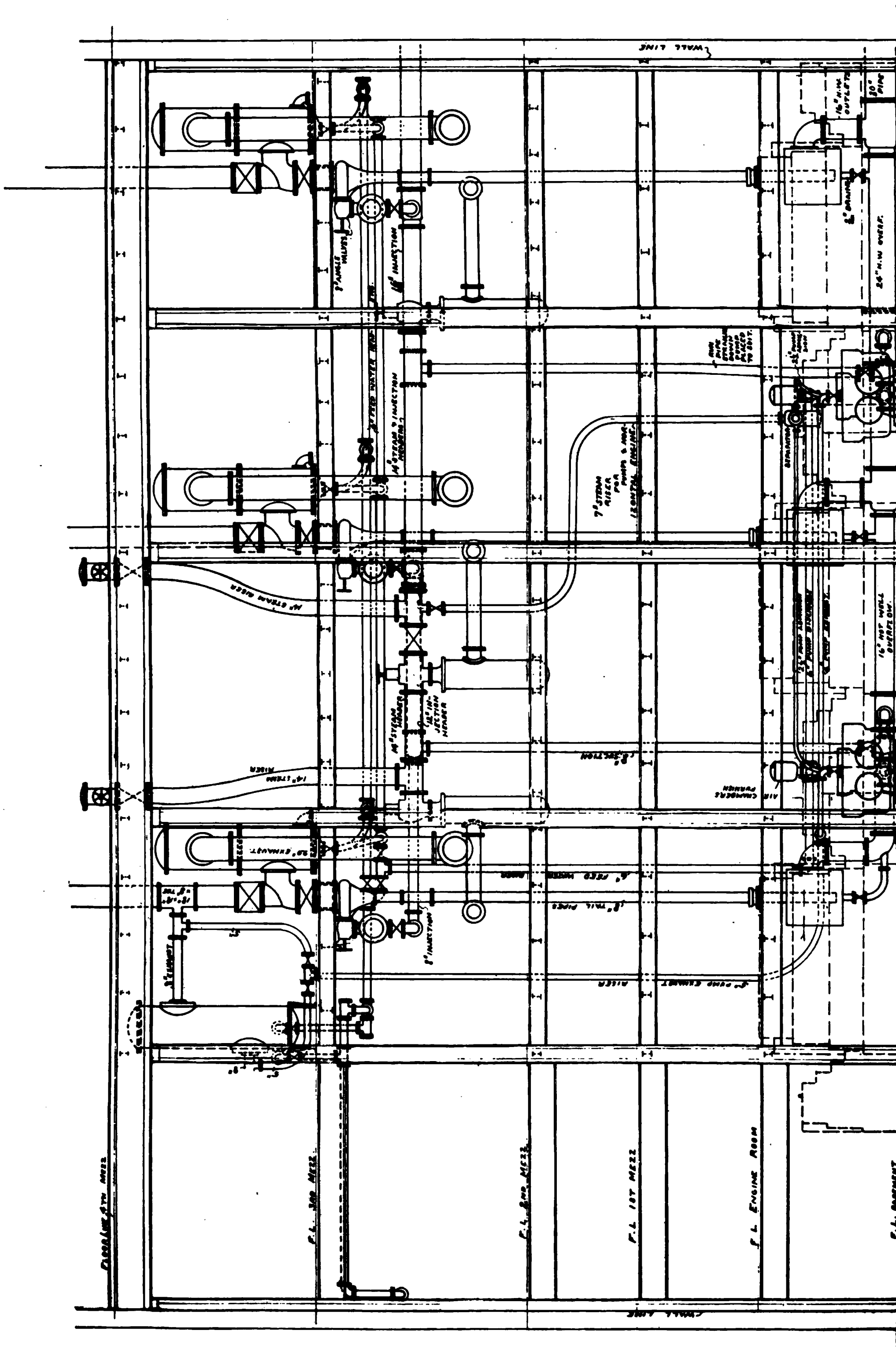


FIG. 81.—Elevation West Mezzanines, Citizens' Light & Power Co., Rochester.

The three drums of the boiler are connected by a standard cross-over pipe for the safety valves and by a special cross-over pipe for the steam connections, both of which are connected to the drums by means of a flexible joint of the ball and socket type. In the case of the safety valve connections the outlets are arranged in the form of a triangle, so that any difference in alignment of the drums will not produce a leak. The steam cross-over connections are laid out with reference to the future use of superheaters, which throughout the design of the plant, has been kept in view. Nozzles have been provided on these cross-over pipes, so that any of the commercial types of superheater can be readily applied to the boiler.

On the front of each drum a combination stop and check valve is provided for the feed-water inlet, the feed water being brought to this valve by means of bent annealed brass pipes fed from a loop main. The blow-off drums, 12 in. in diameter, are fitted with two blow-off connections, which pass out through the side wall of the boiler and are fitted with a standard blow-off valve and special asbestos-packed cock in series.

The safety valves are of extra heavy type, with nickel seats and mufflers.

The outlet nozzle of the cross-over pipe supports a steam-actuated stop and check valve. From these automatic stop valves the 10-in. bent steel pipe connections are made to the 14-in. boiler steam main which is located in the center of the boiler room, running in a north and south direction. These 10-in. connections, where they enter the main, are provided with gate valves. The main itself is provided with cut-off valves at the proper points, so that it may be divided up into sections. Between the second and third mezzanines on either side of the engine room, the 14-in. engine room steam mains are located. These mains are connected with the boiler-room steam mains by means of two 14-in. bent steel pipes, which run near the center of the station from the boiler-room main and through the walls to a tee connection in the engine room above the fourth mezzanine, where they branch downward into a 14-in. connection to the west engine-room main and upward through 12-in. bent steel pipes carried by the lower chord of the main trusses to the eastern side of the station. A foot walk alongside the main is provided in each case. Due provision has been made in all this piping for the taking care of expansion and vibration.

The engine connections are taken from the under side of the main and lead directly into a separator, from which a 12-in. horizontal bent pipe of large radius conducts the steam to the engine throttle. All valves in this high-pressure steam system are by-passed.

THE ENGINES.

The prime movers consist of three vertical cross-compound engines.

Each engine is arranged to drive a 1,360-kw., 2,400-volt, 60-cycle alternator, placed between the low-pressure side of the engine and an outboard pedestal.

The diameters of the cylinders are 28 and 68 in., giving a ratio of 5.9 and the stroke 48 in. They are designed to run at a normal speed of 90 rev. per min., with an initial steam pressure of 160 lb. and a vacuum of 26 in. Under these conditions each engine will develop 1,800 hp. at 30 per cent. cut-off, and a maximum of 3,000 hp. They are, however, built strong enough to work under 200 lb. steam pressure.

When running under most economical load these engines require less than 13 lb. of dry steam per initial hp-hr., including the steam used in the reheater, while the speed variation from no load to full load does not exceed 3 per cent. from the normal. Under any change of load, the internal variation of speed does not exceed one-quarter of one geometrical degree from the position of uniform rotation.

The flywheel is 20 ft. in diameter and weighs, with the armature sleeve, approximately, 125,000 lb. The armature sleeve is bolted directly to the spokes of the generator, thus relieving the shaft of any strain between the flywheel and generator.

The housings, of the bell type, are substantial in construction. The connection rods are solid at the crosshead end and of the marine type at the crank-pin end, while the crossheads are of cast steel with adjustable babbitted shoes.

Economical distribution of steam is accomplished by means of double-ported Corliss valves. They are actuated by separate steam and exhaust eccentrics on both the high and low-pressure side.

These engines use the King regulating device for readily synchronizing the machines. The operator on the switchboard sends current at will through a small motor, which acts as a governor counterweight, thus enabling him to vary to any extent the speed of the engine.

The governor controls the cut-off on both the high and low pressure cylinders.

A jet condenser is provided with each engine, capable of condensing 24,000 lb. of steam per hour and maintaining a vacuum of 26 in. when supplied with cooling water at 75 deg. fahr. The usual automatic free exhaust valve and connections are placed in the exhaust pipe of each engine, and a feed water heater, suitable for 1,800 hp., is connected to each engine exhaust pipe.

The exhaust pipes are galvanized sheet iron pipe and extend from the top of the automatic relief valves near the condenser through the roof, surmounted by standard exhaust heads. The feed water is taken from the hot well or from the city water connections and is handled by two duplex outside packed plunger pumps, 12 by 18 by 9 by 18. These pumps work against 250 lb. water pressure, and either is sufficiently large to handle the entire installation. From the pumps, feed water is taken through the primary heaters, located in the exhaust pipe between the engine and condenser, then to the secondary heater, where it is heated nearly to the boiling point, and thence into the feed mains which run underneath the boilers immediately in front of the ash hoppers, where connections are made to the vertical lines at the side of the boiler, as mentioned above.

Both the primary and secondary heaters are of the even-flow type, with corrugated copper tubes. There are three primary heaters and two secondary heaters. The feed water piping is of the same extra heavy type as the high-pressure steam piping, and the heaters and pumps were specially designed.

CONDENSING WATER.

The penstock of the old station serves as a supply pipe for this water, a 24-in. nozzle being placed on the side of the penstock near the forebay and two 20-in. connections, fitted with valves and strainers are branched into one 20-in. pipe, which runs along the station wall obliquely to a point just below the third mezzanine

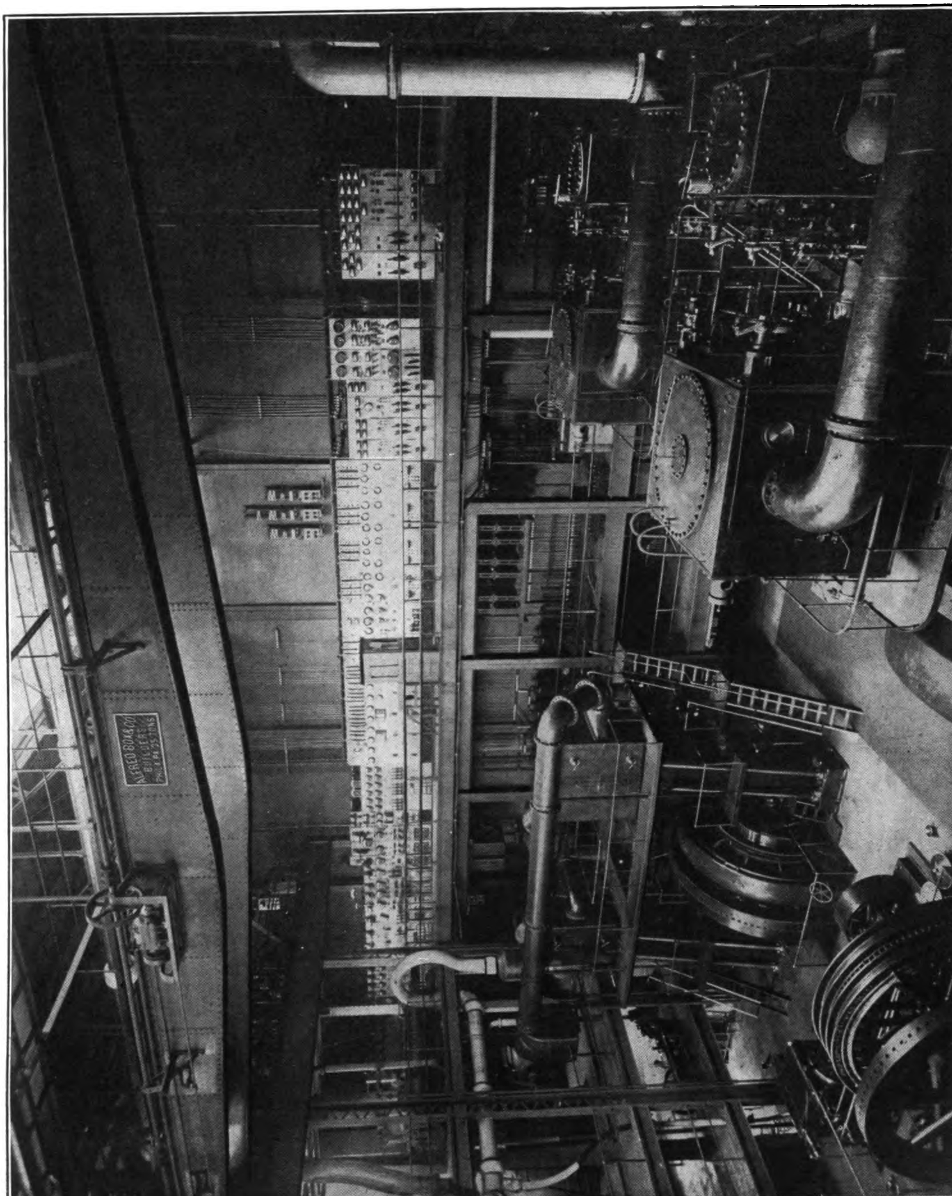


FIG. 82.—Engine Room, Citizens' Light & Power Co., Rochester.

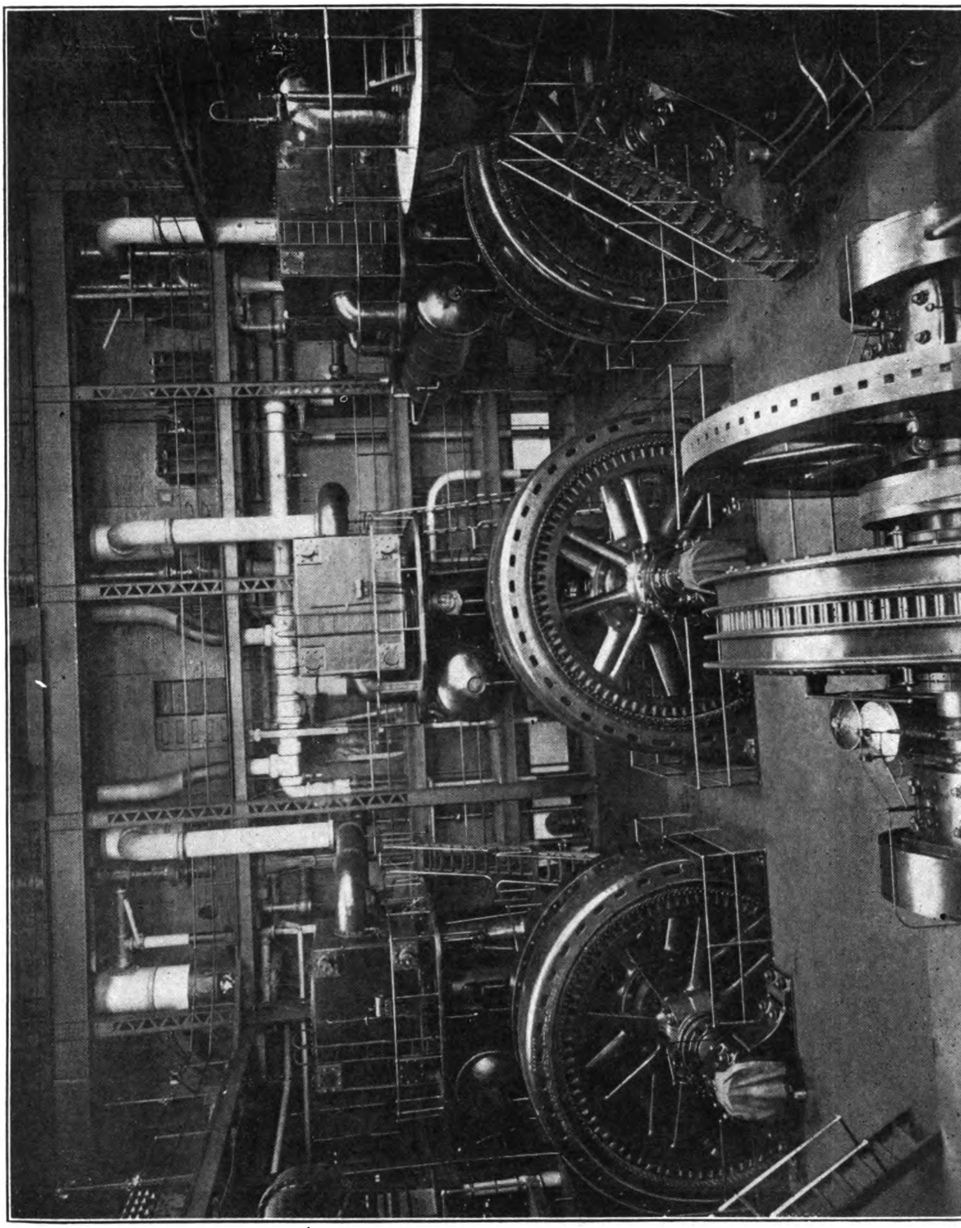


FIG. 83.—Operating Room, Citizens' Light & Power Co., Rochester.

floor on either side of the engine room. Here 16-in. pipes are carried along the mezzanine reducing to 12 in. and 10 in. at the various engines. The injection pipes are taken from this main and are properly provided with injection valves, operated from the floor, and small-mesh strainers. The water from the hot wells overflows into a large cast-iron overflow pipe, which runs underneath the hot wells north to the northerly wall of the station on each side of the engine room, discharging either into the tail race of the old station or through underground pipes to the flat on the bank of the river to the east of the station, where settling and purification tanks may be installed.

The steam lines of the pumps and exciter engines are taken from a 6-in. vertical pipe, which leads down from the main on the north side of the station to a small separator in the basement. All of the auxiliary exhaust steam passes through the secondary heaters, and includes the steam from the four stoker engines, the steam from the two feed pumps, two exciter engines, with enough steam from the receiver of the main engine to heat the feed water to the desired temperature for maximum economy.

In addition, the exciter engines are designed so that they may be worked condensing, in order to get the greatest overload capacity possible to the engine, in event of a breakdown.

THE GENERATORS.

The generating apparatus consists of three 1,360 kw. rated output, 2,500 volts, two-phase, 60-cycle, steam-driven generators, installed in the main station, and three 350-kw., 2,500-volt, two-phase, 60-cycle, water-wheel generators, direct connected to three turbines, installed in the adjoining station, transformed into an extension of the main operating room. The 1,360-kw. steam-driven generators are of the revolving field type. The excitation of present generators is provided by two steam-driven, 75-kw., 125-volt, direct-current exciter sets, and two 100-kw. motor-generator exciters.

In this station were also installed three 500-volt motor-generator sets, to replace the old equipment in the old station, and to provide new capacity for this service. These motor-generator sets consist of two sets of 250-kw. and one set of 500-volt compound wound generators, direct driven by 2,200-volt synchronous motors. The motor generators are started from the direct-current side, and to provide current in case of shut-down of the 500-volt direct-current supply, a 50-kw., 500-volt, direct-current generator has been installed, one end of one of the exciter engine shafts being furnished with a coupling. This small generator is also used to carry light loads as well as for occasionally starting the motor-generator sets.

All electrical connections of generators and exciters, etc., are brought to the operating switchboard on the gallery, running east or west on the south side of the station, and having lateral extension on the east wing of the station. On this gallery, at the center facing the center aisle of the operating room are placed the nine generator panels, with instruments and switching gears on the front of the panel and two sets of buses with transformers, etc., on the back. The main switches are single-throw oil switches, with an independent oil tank for each of the four legs of the two-phase circuit.

THE WASHINGTON STREET POWER STATION OF THE UTICA GAS & ELECTRIC COMPANY

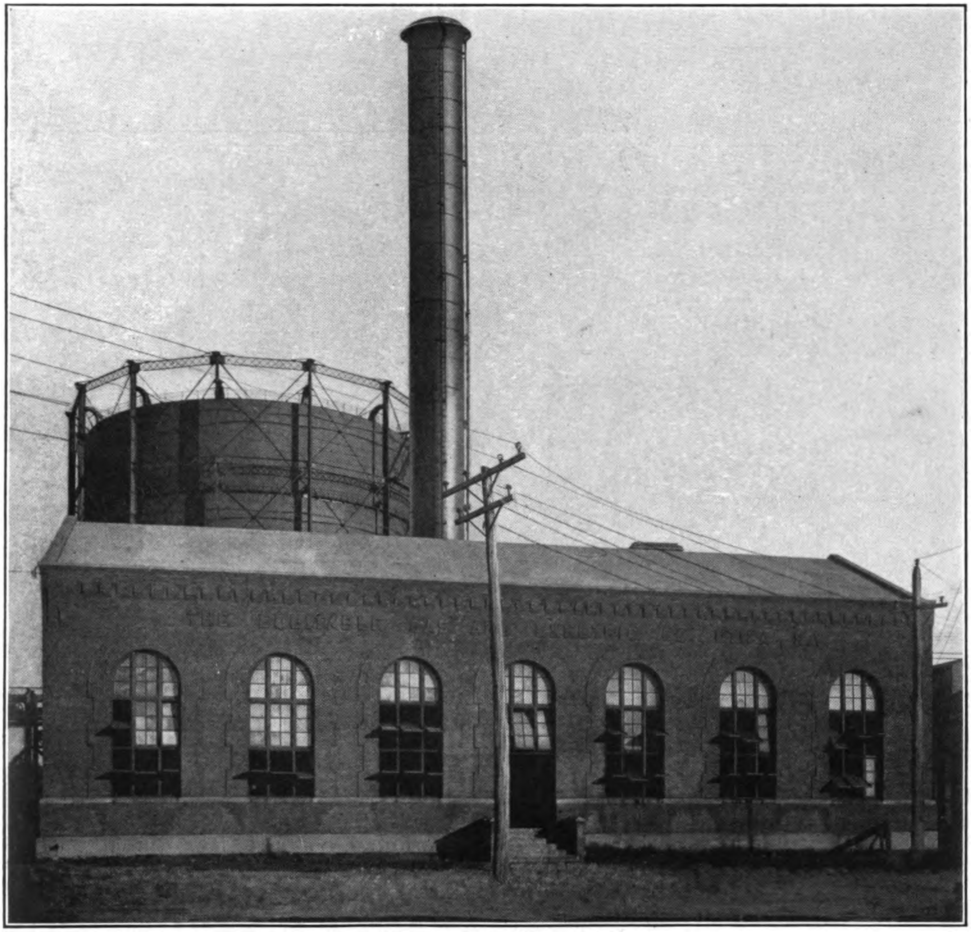


Fig. 84.—Front View Washington St. Power Station, Utica Gas & Electric Co.

THE WASHINGTON STREET POWER STATION OF THE UTICA GAS & ELECTRIC COMPANY.

GENERAL.

The principal steam station of the Utica Gas and Electric Company is located on the company's property on Washington Street, Utica, between the tracks of the New York Central and the Mohawk River.

The property on which the station is situated extends back to the river some 1,400 ft. and slopes off considerably as it approaches the river, and this land is being filled by the ashes from the power house. As the amount of ashes from a station of this size is comparatively small, they are hauled by carts to the edge of the fill and dumped. This fill is about 10 or 12 ft. high, so that it will be a number of years before the property is all filled in.

The building itself is a single-story structure of brick and steel, approximately 121 by 100 ft., and is divided by a brick division wall into a boiler house 44 by 121 ft. and an engine room 55 by 121 ft. The foundations are formed by driving piles and the concrete piers for supporting the columns and also the foundations for the machinery are erected on the piles.

The coal supply is obtained by rail, a spur track leading onto the property, running at right angles to the boiler house. The cars are dumped, forming a pile of coal on each side of the track. The coal is carted from these piles and dumped in a storage shed back of the boiler room wall. In this wall are several small gates through which the coal falls by gravity, to the boiler house floor. This affords a large reserve storage of coal in case of emergencies resulting from temporary failure of the coal supply.

The water for condensing purposes is brought from the Mohawk River in a 16-in. pipe, approximately 1,200 ft. long, furnishing an ample supply of injection water at the heaviest loads. Jet condensers are used throughout the station.

The stack is of steel, 150 ft. high and 10 ft. in diameter, and is located in nearly the center of the length of the boiler house. It receives the products of combustion from four 280-hp. Aultman and Taylor boilers on one side, and two 650-hp. Babcock and Wilcox boilers and one 650-hp. Aultman and Taylor boiler on the other. Flat dumping grates are used on all the boilers on which is generally burned a mixture of No. 3 Buckwheat and soft coal. The two Babcock and Wilcox boilers are equipped with Foster superheaters which superheat the steam to about 100 deg. fahr. above the temperature due to the pressure carried. A steam-driven fan is used for forced draft, the air duct being carried under the floor.

The engine room contains one horizontal 1500-kw. turbo-generator running at 1800 rev. per min. In addition to the turbo-generator there are installed one 1200-hp. cross-compound engine with 26-in. and 50-in. cylinders and a 48-in. stroke, direct-connected to a 750-kw. inductor alternator running at 90 rev. per min., and two 750-hp. cross-compound engines, 20-in. and 38 by 42-in., direct-connected to two 500-kw. inductor alternators running at 100 rev. per min. This makes the total rated capacity of the station 3,250 kw.

These units are all run condensing, using jet condensers exclusively.

The 750-hp. engines exhaust into a jet condenser using a pump driven by a lever from the low-pressure crosshead of the engine. A 15-ton, hand-operated crane spans the engine room on rails attached to the columns.

The general layout of the feed water system is shown very plainly in the drawing and has been designed with a view to utilizing as much as possible of the heat rejected in the engine and auxiliary exhausts. The suction of the feed pumps is taken from the hot wells at a temperature of about 125 deg. fahr. A 6-in. line to the city mains has been laid to supply the feed pumps when the station is run non-condensing. There are three feed pumps of the duplex, outside end packed, plunger type, 7½ by 4½ by 10 in., and one 8-in. and 12 in. by 7 by 12-in. compound, duplex, outside packed pump. These pumps discharge in common into a 4-in. line to the one closed feed water heater containing 234 sq. ft. of heating surface, located in the north end of the station, and thence through another 4-in. line to the boiler connections, and also through one closed feed water heater containing 400 sq. ft. of heating surface, and thence through a 5-in. line to the boiler connections.

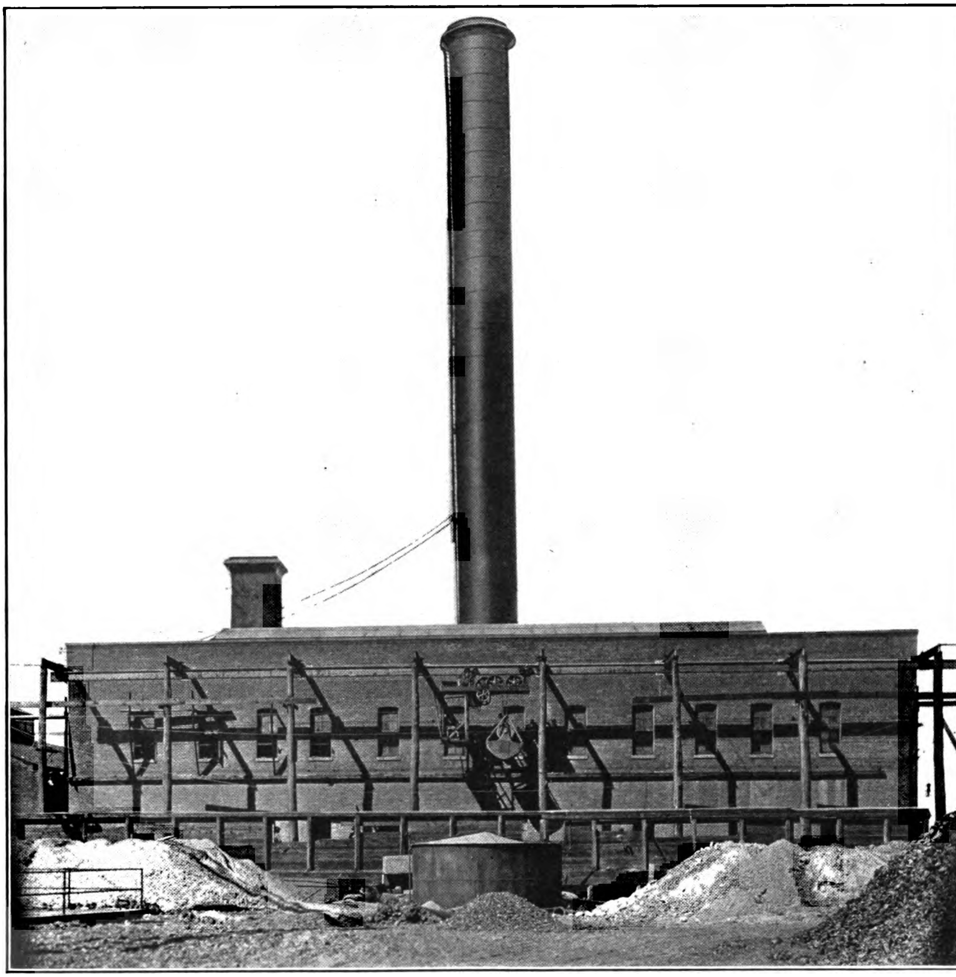


FIG. 85.—Coal Handling Machinery, Washington Street Station, Utica Gas & Electric Co.

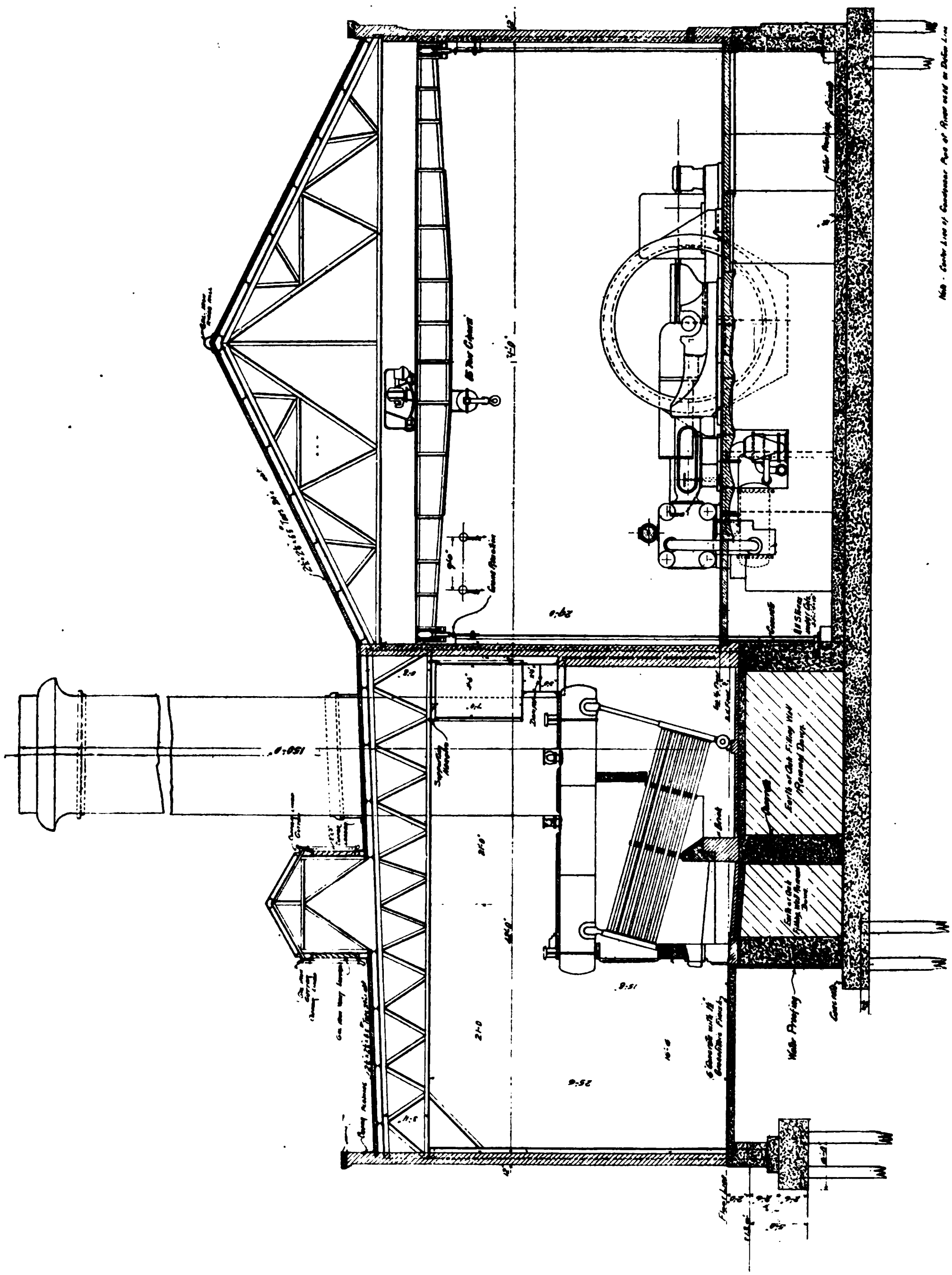


FIG. 86.—Cross Section, Utica Gas & Electric Co.

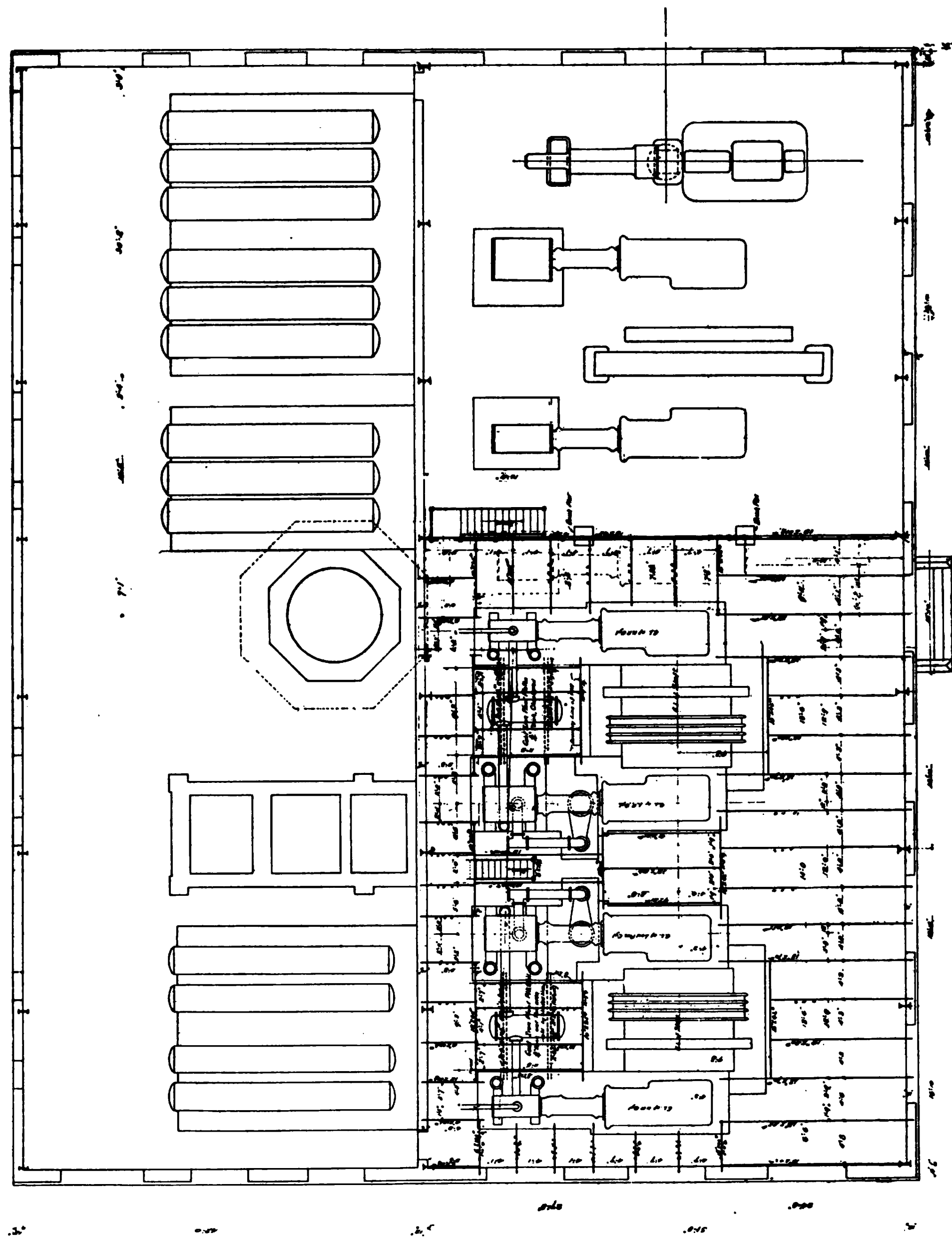


Fig. 87.—Plan of Engine Room Floor, Utica Gas & Electric Co.

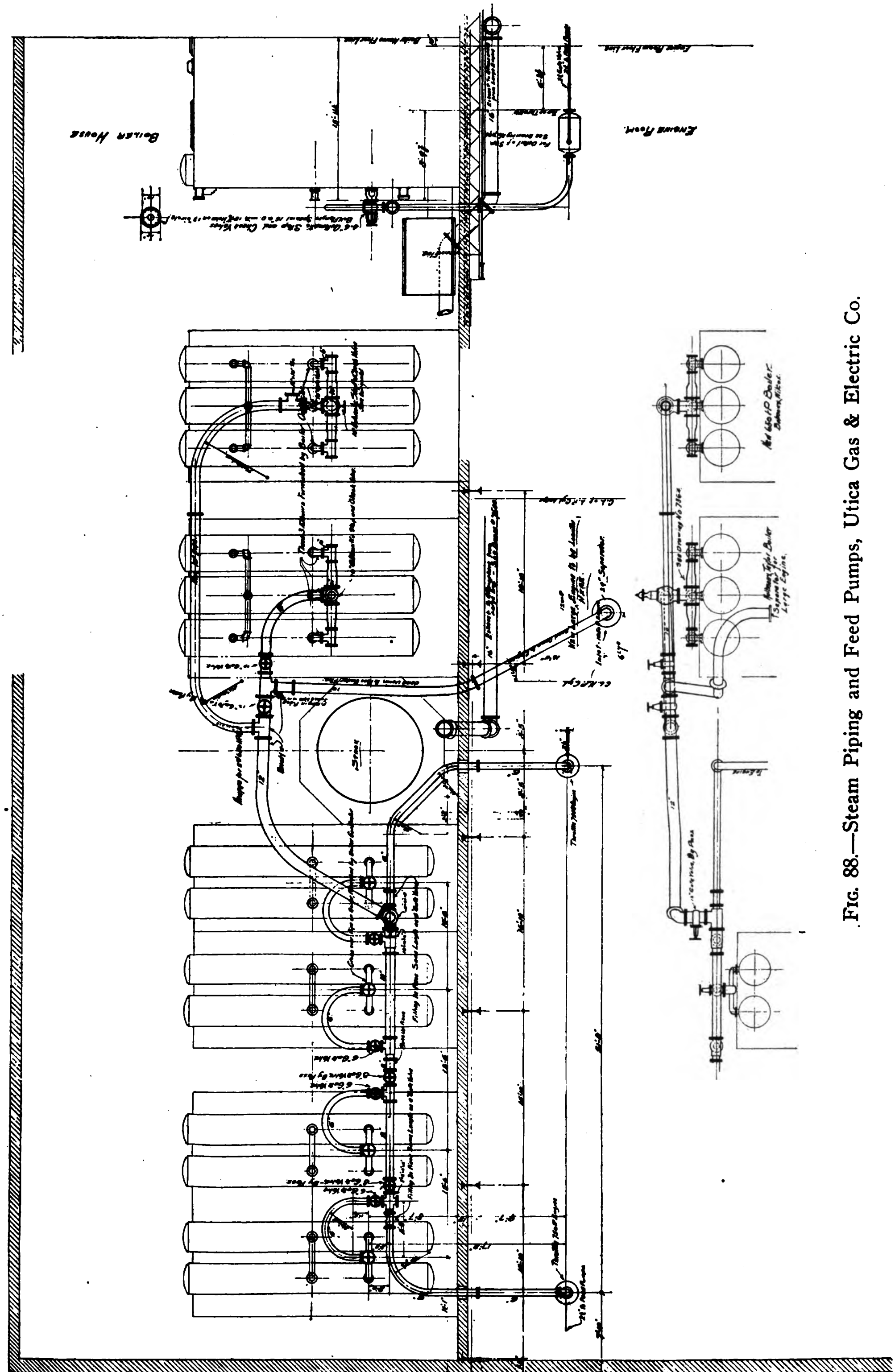


FIG. 88.—Steam Piping and Feed Pumps, Utica Gas & Electric Co.

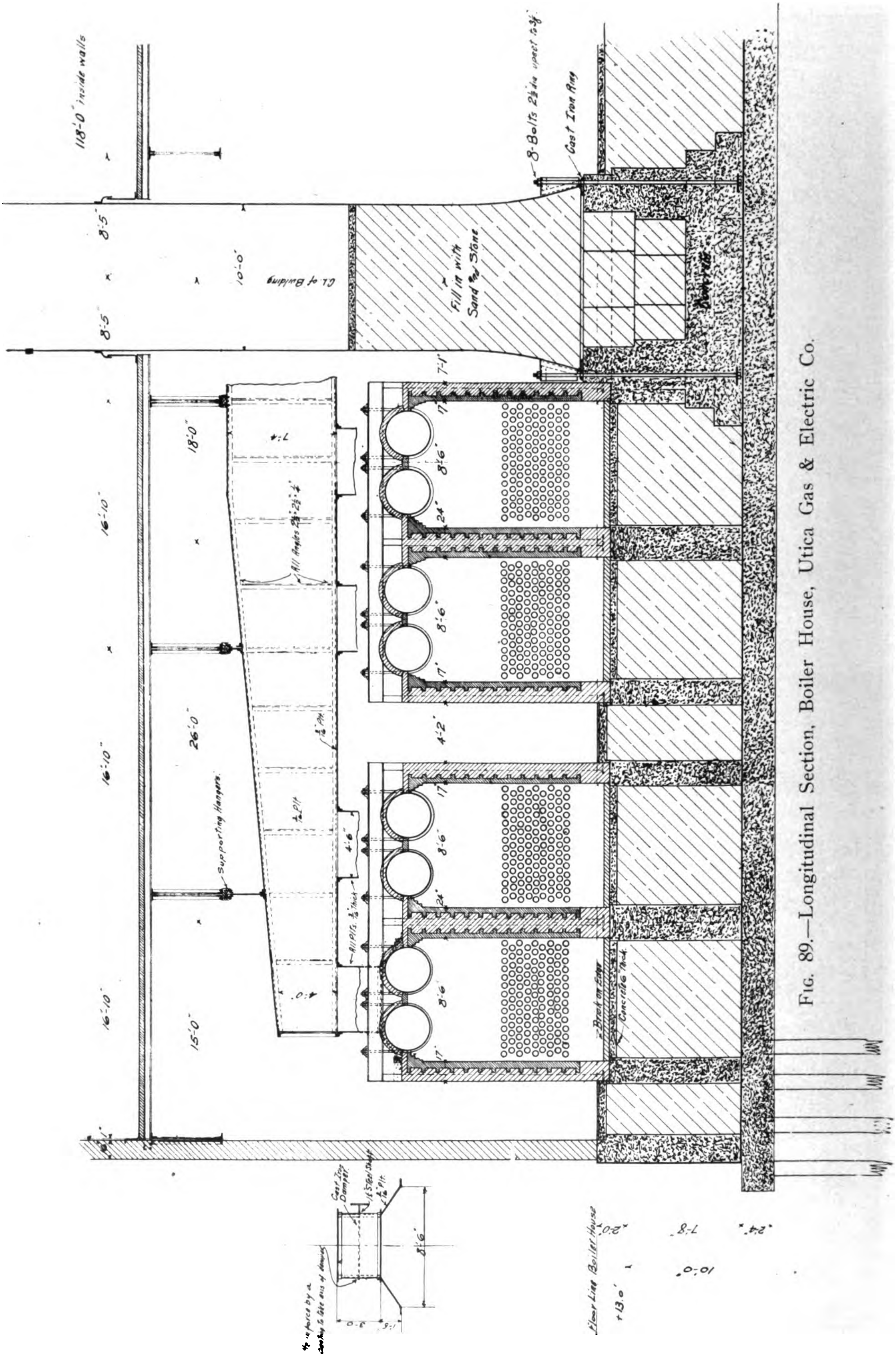


FIG. 89.—Longitudinal Section, Boiler House, Utica Gas & Electric Co.

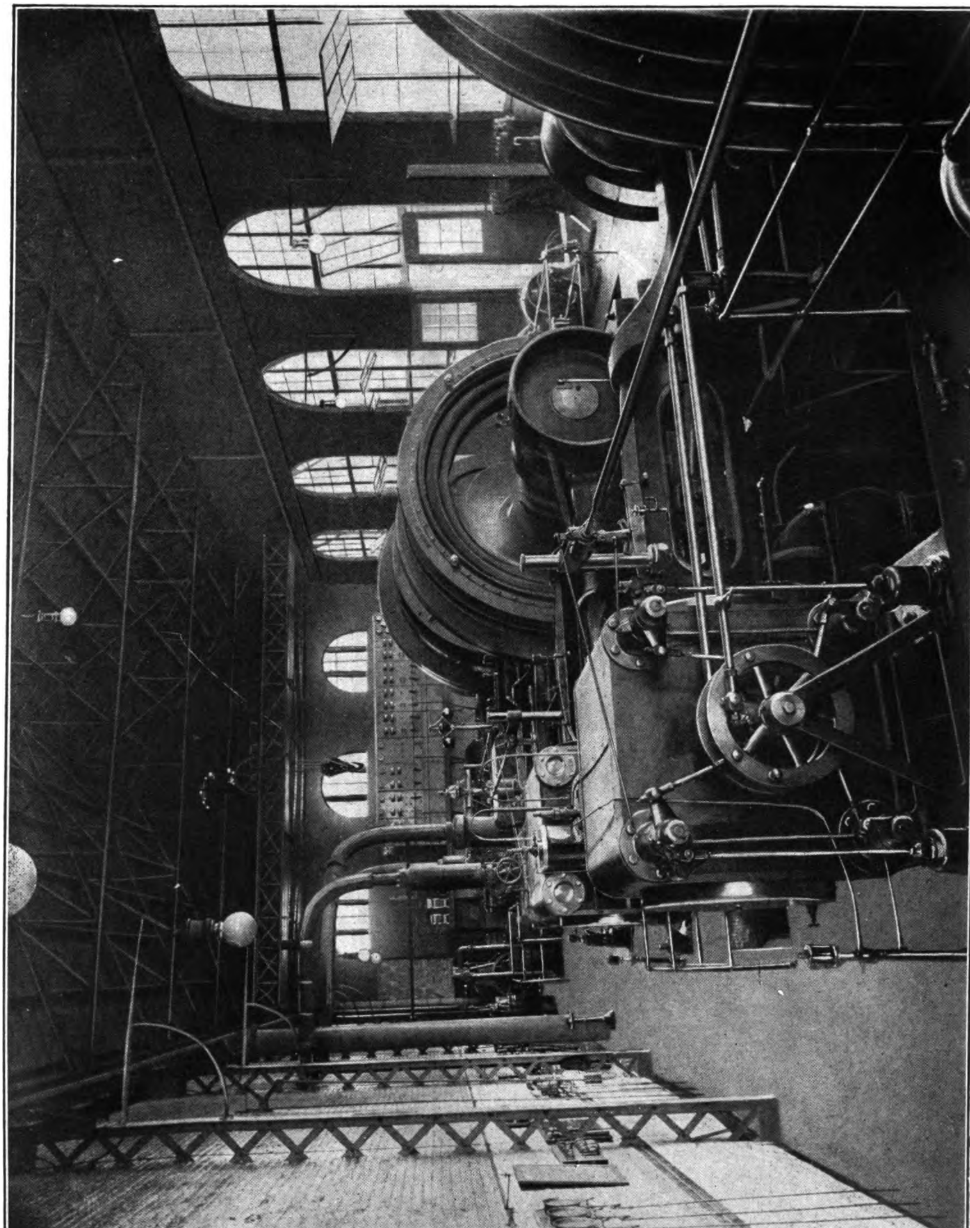


FIG. 90.—Operating Room, Washington Street Station, Utica Gas & Electric Co.

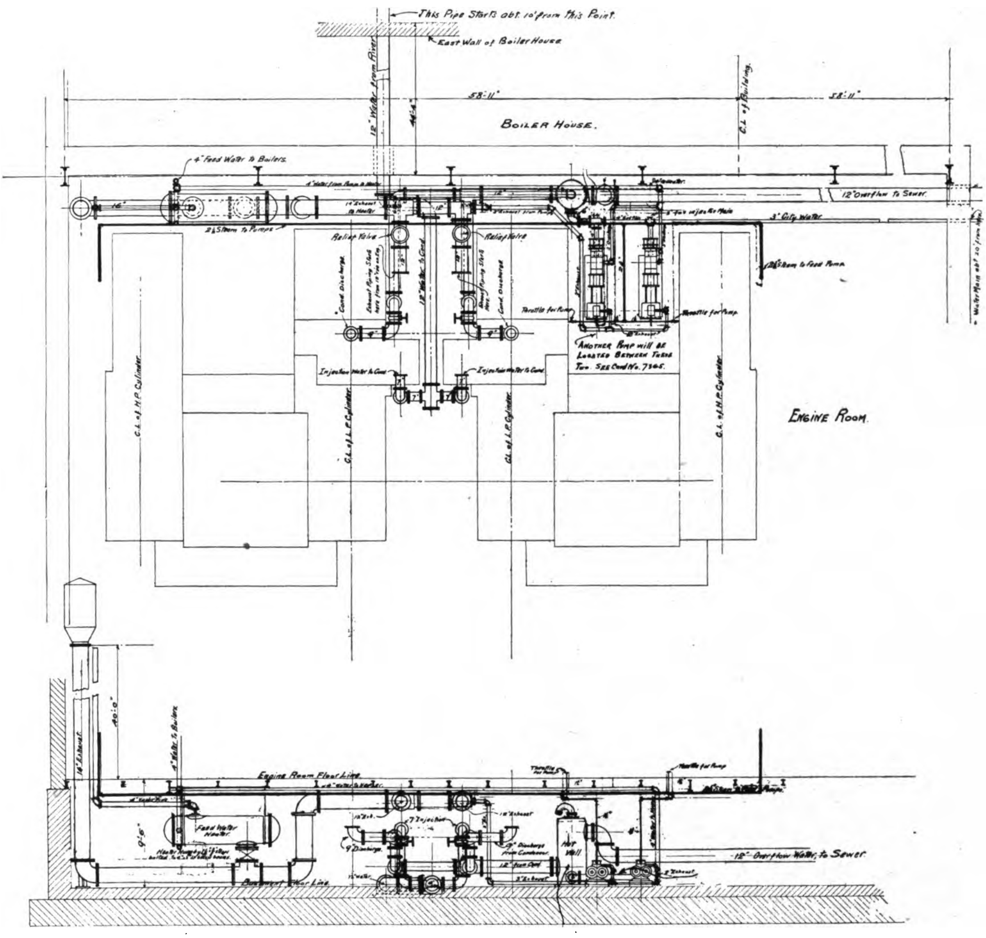


FIG. 91.—Piping Below Engine Room Floor, Utica Gas & Electric Co.

The feed water heaters are located at a dead end in the system, the condensation of the steam in the heater producing a vacuum which draws the steam into the heater. A 4-in. vent pipe is provided to prevent any accumulation of air in the heater, which would greatly impair its efficiency if allowed to collect. The heaters take their steam from the exhausts of the feed pumps and the exciter engines, and when the station is running non-condensing, from the main prime movers. The feed water after leaving the heaters passes through a filter.

In case of any accident to the feed pumps, which might put them out of service, two injectors are connected to the city water main to feed the boilers with cold water.

The layout of the main steam line is shown in the drawing, and consists essentially of one header connected with the four 250-hp. boilers, from each end of which a 6-in. lead runs to the two 750-hp. engines, and another header connecting the three 650-hp. boilers, and having a 10-in. lead to the 1200-hp. engine and also to the turbine. These two headers are connected by a 12-in. line and the valves are so arranged that the whole steam system may be inter-connected or run on the unit system as is desired.

Excitation for the alternators is furnished by one 75-kw. generator direct connected to a 9½-in. and 17 by 10-in. vertical compound engine and by two 30-kw. motor-generator sets.

The switchboard of blue Vermont marble is in a gallery at the south end of the engine room, and consists of one exciter panel, four generator panels, one feeder panel and three transformer panels for controlling the secondary of the step-down transformers through which current from the water power plant at Trenton Falls is delivered to the bus-bars, and in times of shortage of water power, is delivered to the transmission lines mentioned later. Two 2400-volt, two-phase feeders deliver current for distribution to a substation in the heart of the city. This station is used chiefly as an auxiliary to take care of overloads on the water power plants, and as a reserve to take care of deficiency of water power and interruption in the transmission system.

The location of this station being at the center of the 22,000-volt, three-phase transmission system of the company, a few words regarding this system, and the water power plants with which the station is operated in parallel, seem appropriate here. At Trenton Falls, on the West Canada Creek, the company has a 4000-kw. plant operated under a head of 265 ft. Four 1000-kw. vertical shaft three-phase generators deliver current through six 666-kw. air-blast transformers to a double three-phase tansmission line which runs south 12½ miles to Utica. Current for Utica is stepped down to 2400 volts, two-phase through six 500-kw. air-blast transformers and delivered to the bus-bars in the steam station for distribution.

A single three-phase line runs west from this station 15 miles to Rome for furnishing light and power in that city, and about four miles from Utica a branch is taken off this line and runs south two miles to the village of New York Mills, where the company has a 1200-kw. sub-station for supplying power to the extensive cotton mills and tool factory in the vicinity and lighting

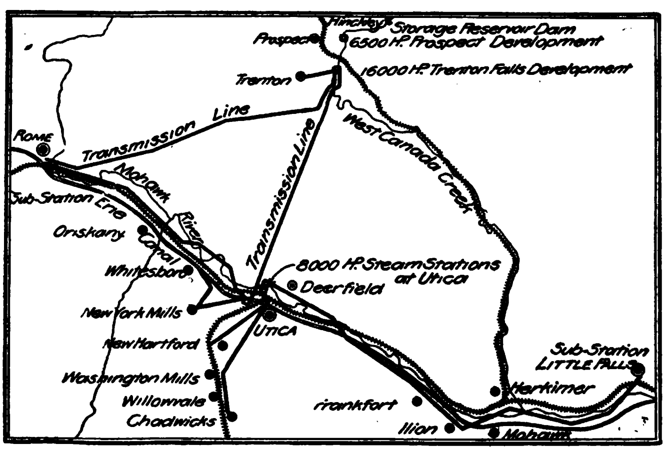


FIG. 92.—Map of Transmission Line, Utica Gas & Electric Co.

to the villages of Yorkville, New York Mills, Whiteboro and Oriskany. Another single three-phase line runs east from this station 22 miles to Little Falls with substations for lighting and power in the villages of Frankfort, Ilion, Mohawk and Herkimer. At Little Falls the company has on the Mohawk River a 430-kw. steam and water power plant operating under a head of 18 ft., and in connection with this 1250-kw. of step-down transformers.

At Dolgeville, on the East Canada Creek, 9 miles north of Little Falls, the company has a 2100-kw. water power plant operating under a head of 72 ft., connected by a single three-phase line with Little Falls, where it meets the line from Utica. All these plants are operated in parallel, the synchronizing being done on the 22,000-volt side by means of an automatic synchronizer in this station.

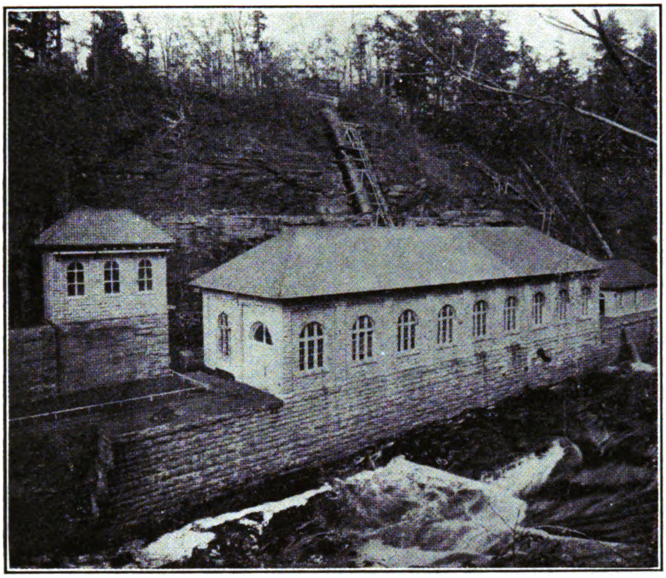


FIG. 93.—Trenton Falls Power House, Utica Gas & Electric Co.

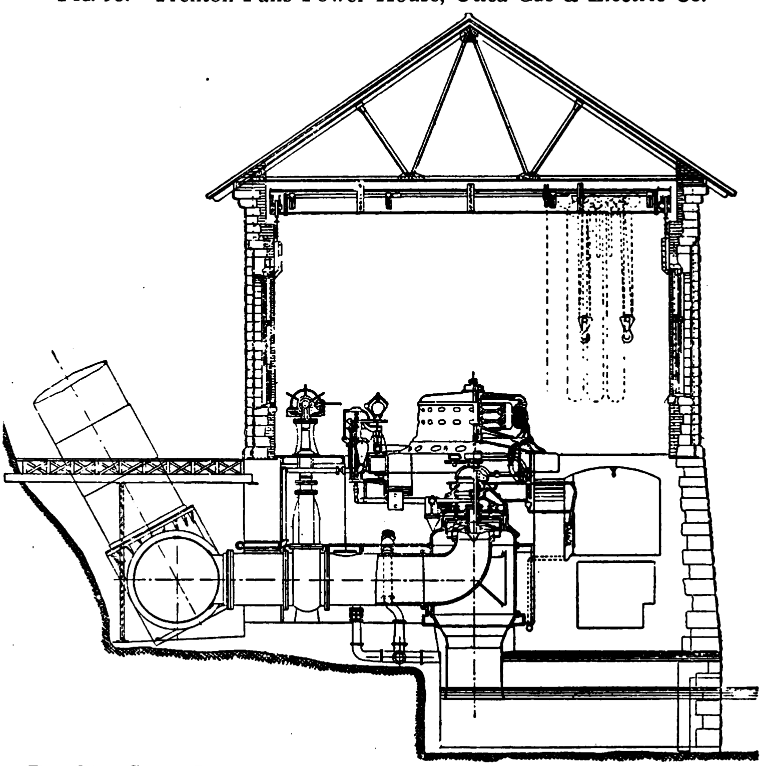


FIG. 94.—Cross Section of Trenton Falls Power House, Utica Gas & Electric Co.

POWER PLANT
OF THE
HELDERBERG CEMENT COMPANY

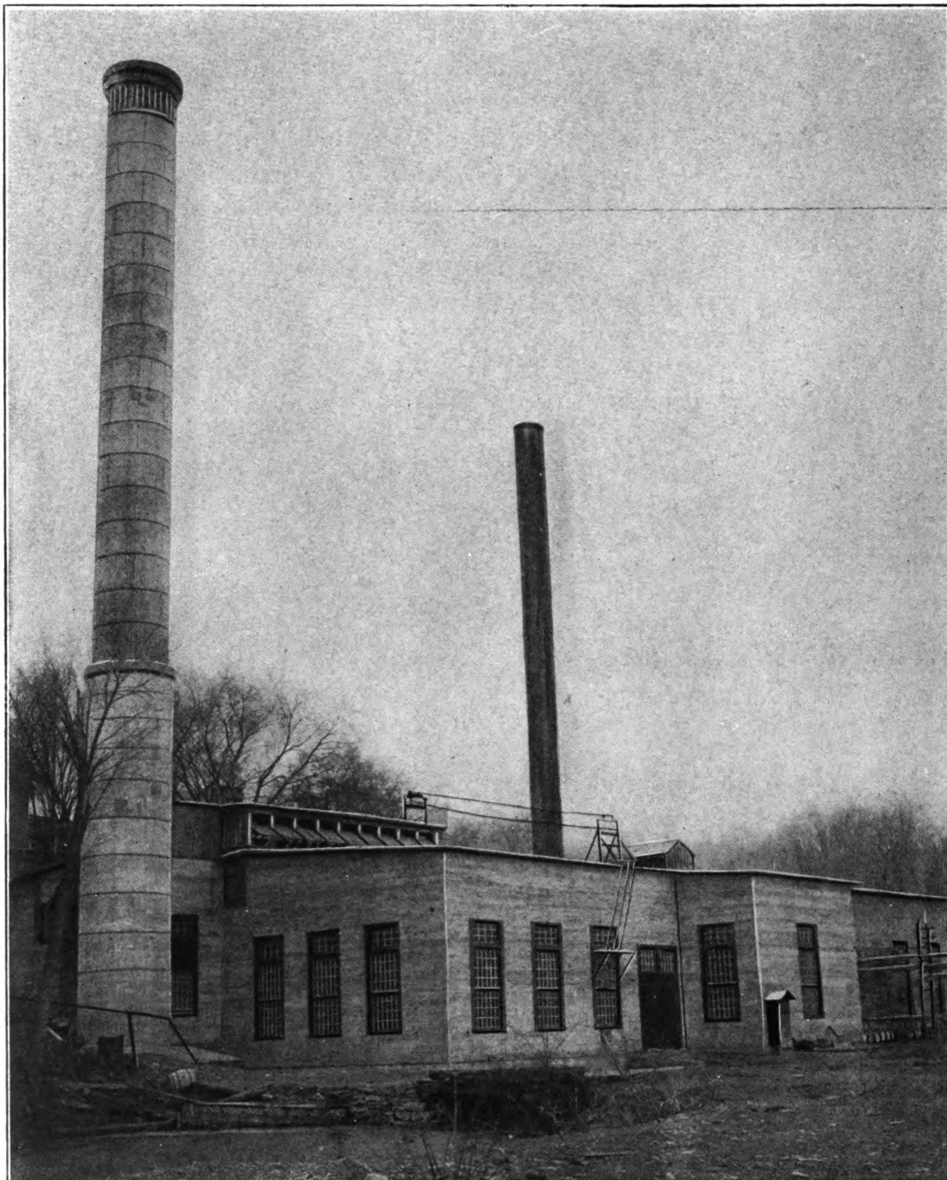


FIG. 95.—Power House, Helderberg Cement Co.

POWER PLANT OF THE HELDERBERG CEMENT COMPANY.

GENERAL.

The Helderberg Cement Company, of Howes Cave, N. Y., are manufacturers of the Helderberg brand of Portland cement. The location of the plant was principally determined by the presence of the materials needed for the production of the best grade of Portland cement. A fortunate coincidence was the presence of a large mill pond which formerly supplied water for the operation of a water-driven mill, in which for 30 years natural cement had been produced. In 1898 the production of Portland cement was first undertaken at this place, and in 1900 considerable enlargements of the plant were made and further increases in the producing capacity of the works have been made from time to time.

AVAILABLE POWER.

At the time of the first great increase in 1900, a plant for the production of electric power from water power was undertaken by another company on a stream about 20 miles distant, and it was first intended to drive the machinery in the enlarged plant at Howes Cave by electricity, generated at this water-power plant. This was to be transmitted at about 11,000 volts, and then stepped down by transformers at Howes Cave to 440 volts for use with the three-phase motors which were installed in the new plant. With this in view, a transformer house was built, where the high-tension lines entered the grounds and a switchboard with distributing panels controlling each department of the cement works was installed in the same house, all distributions to departments being at the lower voltage. While the enlargement of the plant was under way, it became evident that there would be at certain seasons of the year a deficiency of water in the stream on which the water power company relied, which would at times make it impossible for them to supply the power for which they had contracted. As this season would probably coincide with the most active shipping season of the cement company, it was decided to build a steam plant which would enable the cement company to carry all the load when necessary, or part of the load if de-

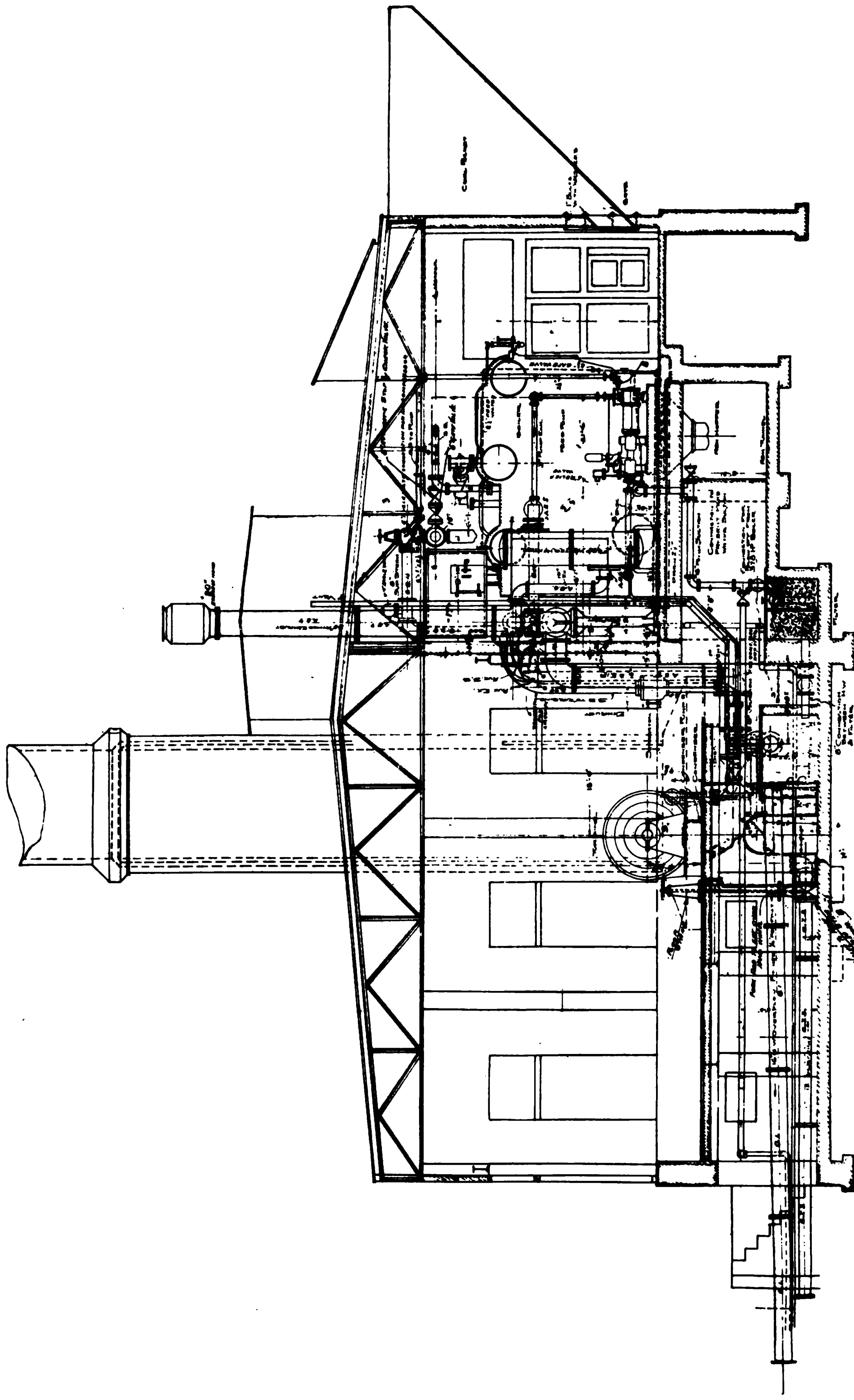


FIG. 96.—Cross Section, Boiler and Engine Room, Helderberg Cement Co.

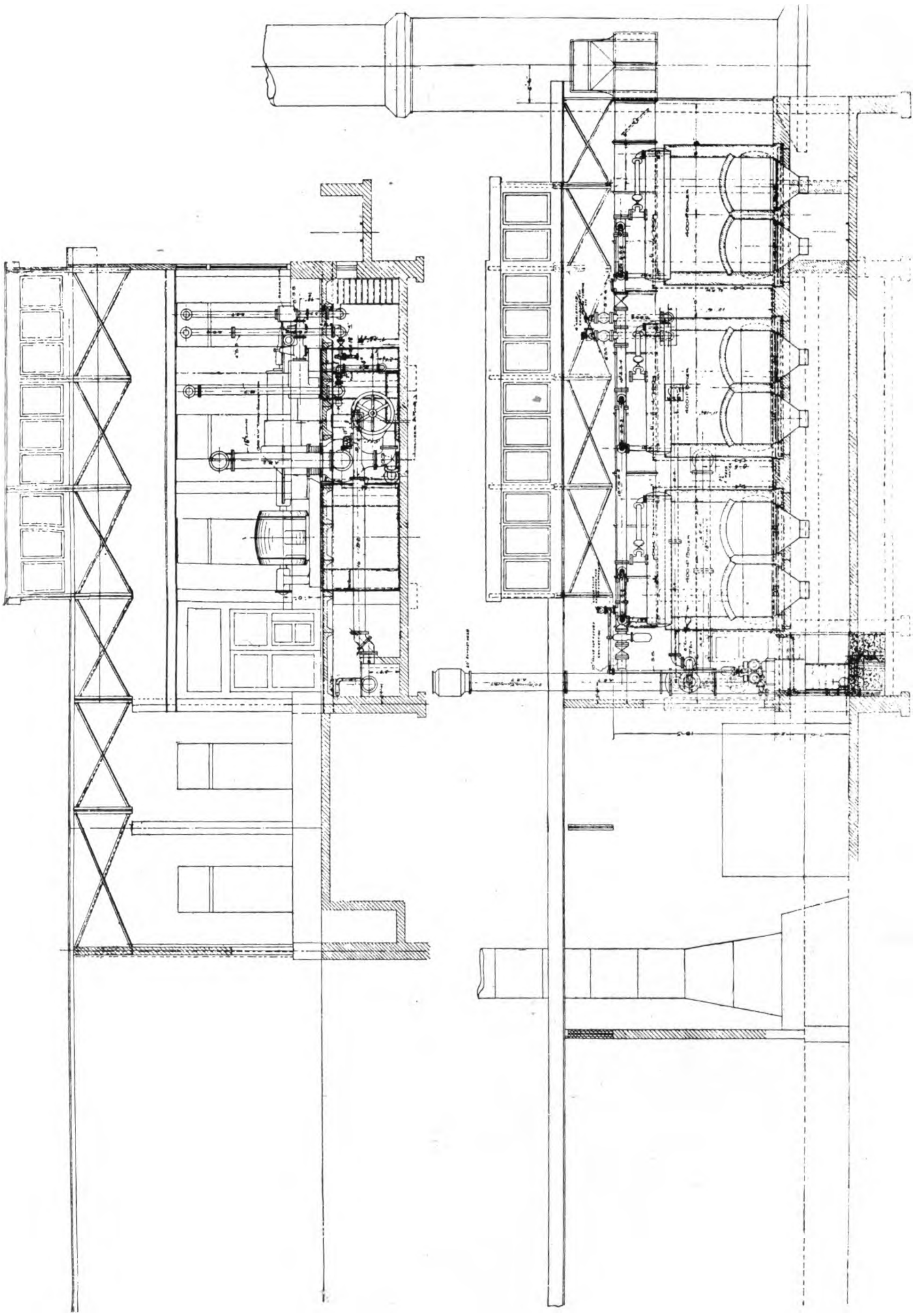


Fig. 97.—Longitudinal Section, Boiler and Engine Room, Helderberg Cement Co.

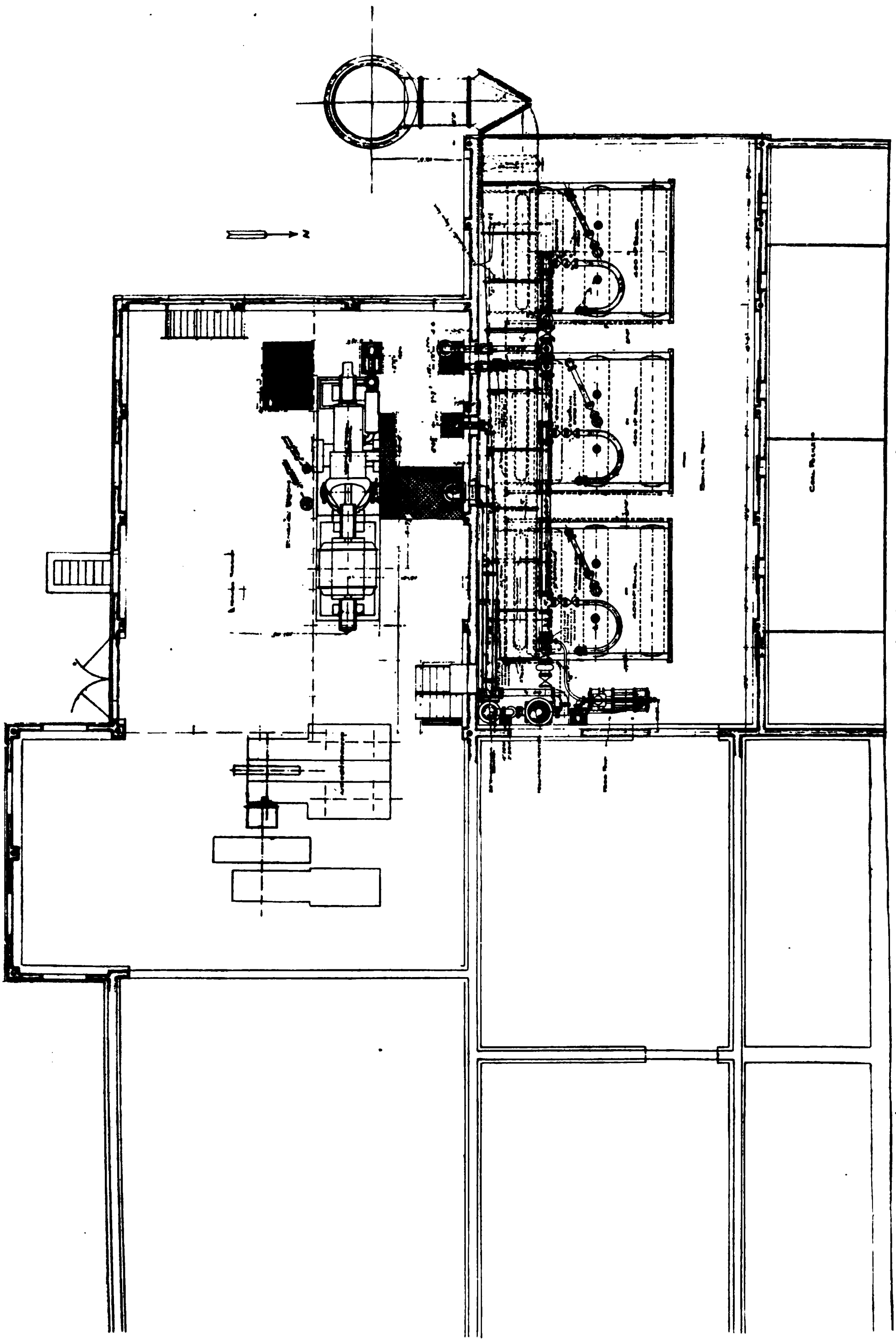


FIG. 98.—First Floor Plan, Helderberg Cement Co.

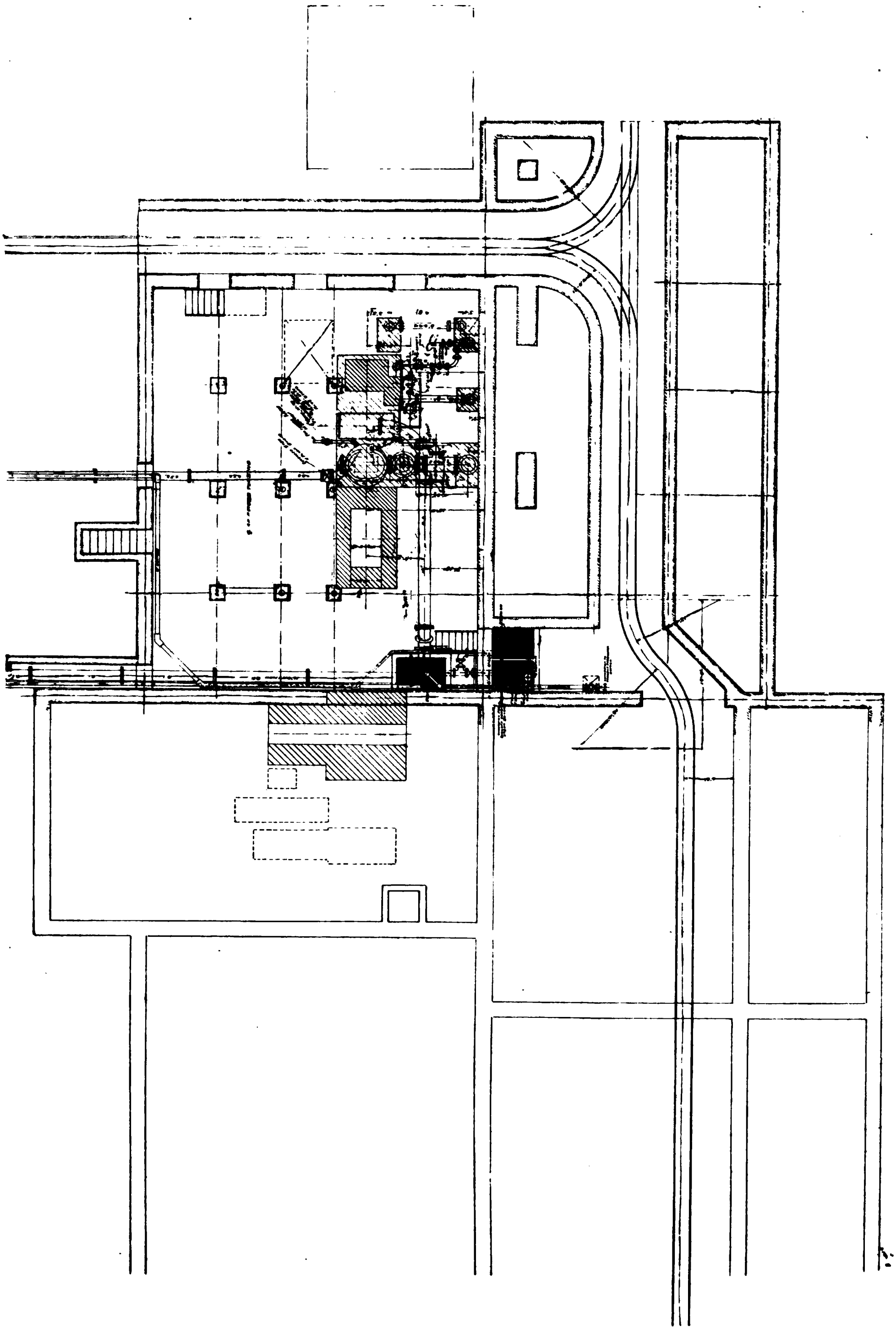


FIG. 99.—Basement Plan, Helderberg Cement Co.

sired, and to locate this plant near the old mill pond where ample water supply was available, and where also it was possible to use gravity in the delivery of the coal supply.

NEW POWER PLANT.

As this plant was only about 800 ft. from the transformer house in which the distributing switchboard was located, it was thought best to generate the power at 440 volts and transmit the short distance in large cables, instead of undertaking to generate at a higher voltage and transform after such a short transmission.

As the utmost expedition was required in the building of this plant, the foundations of the boilers, machinery and building were first put in, a light steel frame work to support the roof was hastily erected, and the machinery was actually in operation while the concrete walls of the building were being completed. The walls of the building and foundations under the machinery are of monolithic concrete, while the floors are concrete, reinforced.

GENERAL LAYOUT.

The equipment of the first plant consisted of two 20 by 38 by 42-in. Corliss cross compound, condensing engines direct connected to two 500-kw. generators running at 100 rev. per min. These machines operate at 440 volts and 60 cycles. The original boiler equipment consisted of three 200-hp. Stirling watertube boilers, to which, first, one 200-hp. Stirling boiler was added, and afterwards one 387½-hp. Stirling boiler.

After this power plant, which was at first intended as an auxiliary plant, had been in operation only a short time it was discovered that the conditions under which the water power company was operating were such that it would be impossible for it to deliver much power at any time, and finally its efforts to furnish power were abandoned, and so the steam plant had to be relied upon entirely Certain improvements were made, notably the addition of an exciter engine, a feed water heater, additional feed water pumps, and the extra boiler capacity above mentioned, all of which tended to make the plant more certain and economical in its operation, and it is of record that for three years the plant operated continuously at full load with delays not exceeding a few hours at a time during the period. As further enlarge-

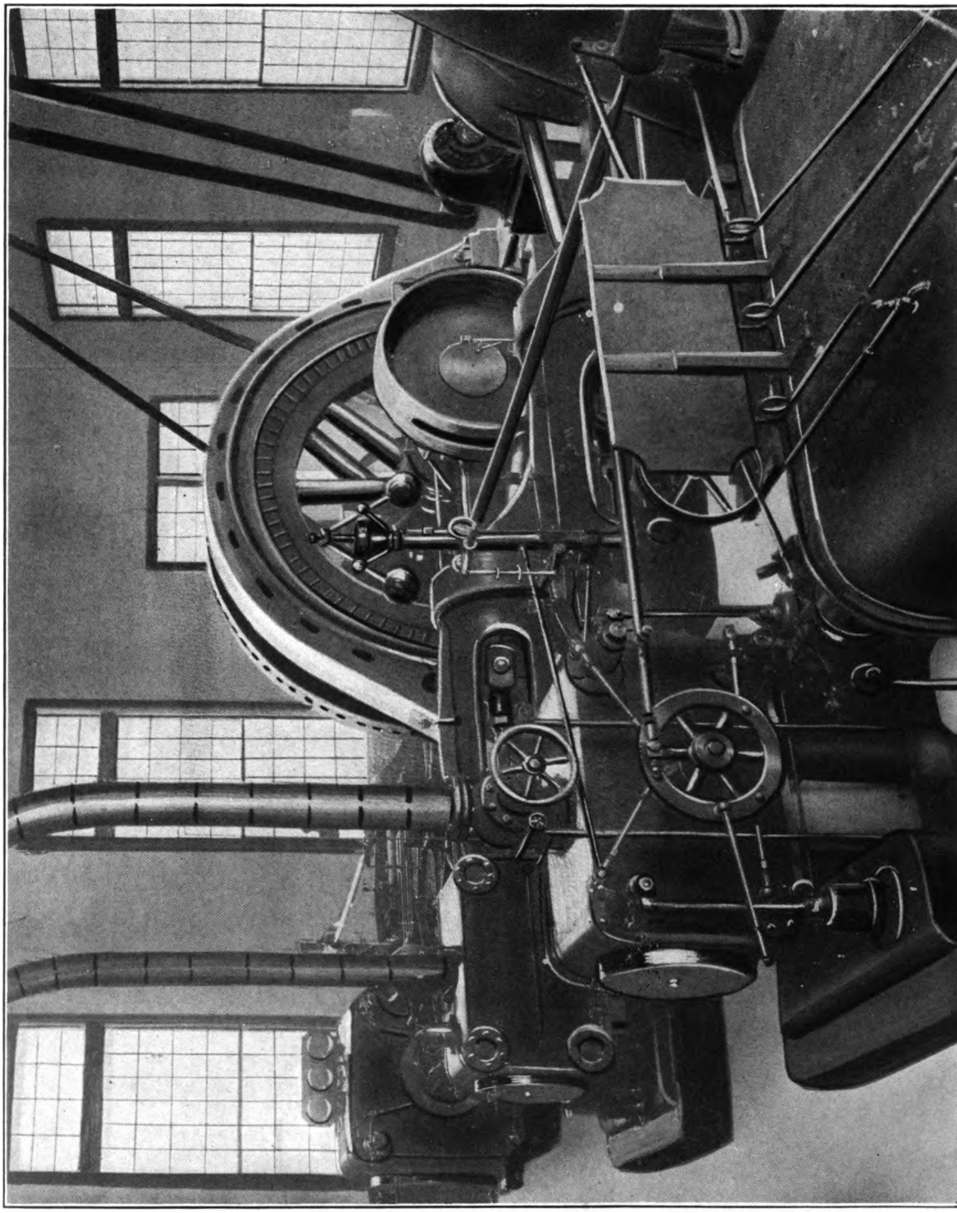


FIG. 100.—Engine Room, Helderberg Cement Co.

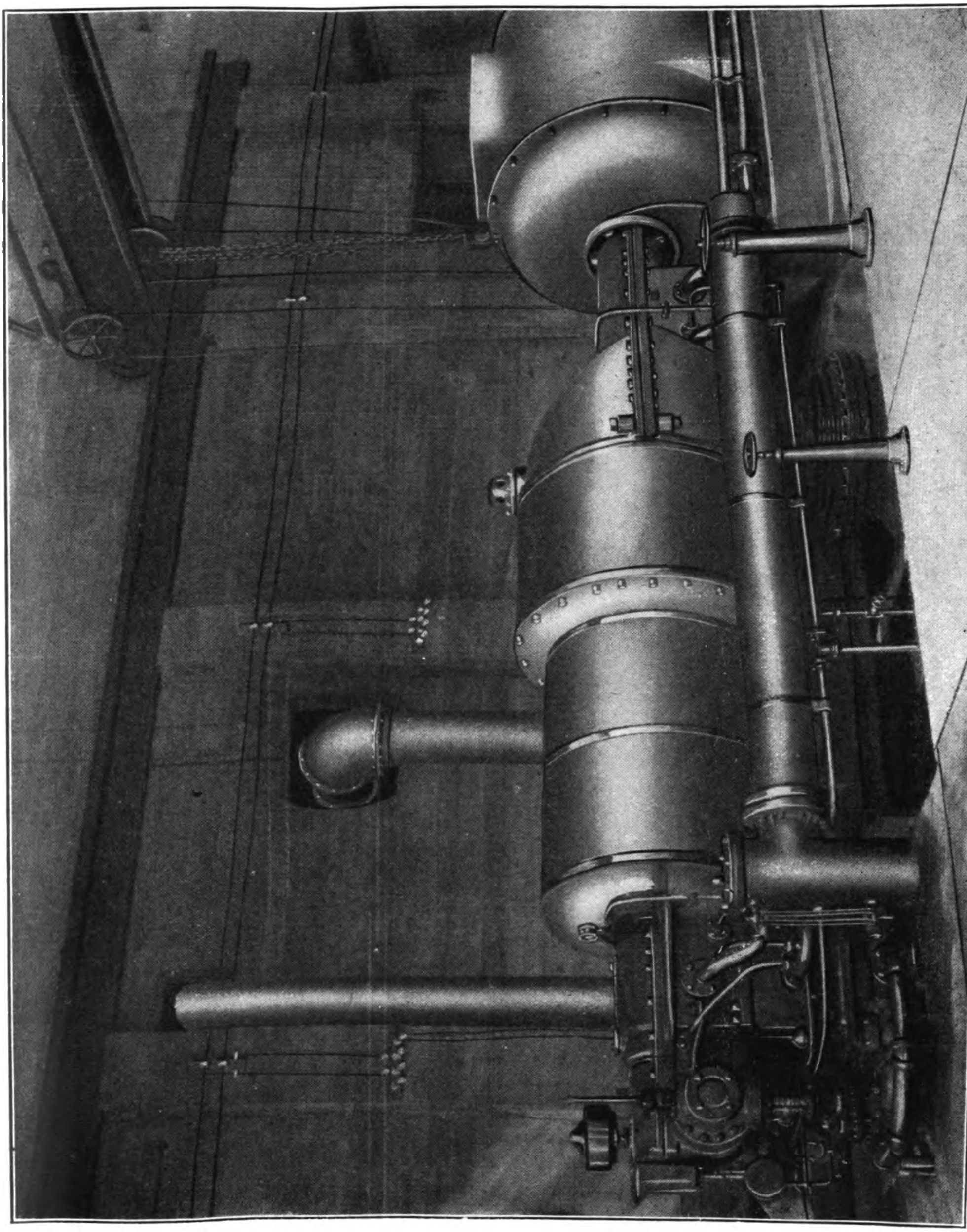


FIG. 101.—Turbo-Generator, Helderberg Cement Co.

ments of the cement plant took place, additional power was required, and a turbine plant, a description of which follows, was installed.

The machinery in the plant is run by three-phase induction motors, 400 volts, 60 cycles, the motors varying in size from 2 hp. to 100 hp.

The new boiler equipment consists of three 407-hp. Stirling boilers, each with U tube superheaters for 100 deg. superheat, with 150 lb. pressure. The old boilers are connected to a self-supporting steel stack, while the new boilers use a concrete stack 140 ft. high, 9 ft. inside diameter.

Any one of three 12 by 7 by 10-in. outside packed plunger feed pumps may be used to feed the boilers. The feed water passes through a 3000-hp. heater, which takes steam from the auxiliaries. The steam piping from all the boilers is connected to one main, with suitable separators to insure dry steam for mixture with superheated steam for the turbine.

The new steam power equipment consists of one horizontal turbine running at 1800 rev. per min., of a rated capacity to drive a 1500-kw. generator, operating at 440 volts and 60 cycles. Directly beneath the turbine is a three-lobe cycloidal pump direct connected to a horizontal engine and a jet condenser. The pumps for the Corliss engine are directly beneath the low-pressure crosshead, and connected to the latter by links. A jet condenser is installed for these units; water for steam and condensing purposes is obtained from a storage pond fed from Cobleskill Creek. Cooling water for the turbine and compressors is secured from springs at a higher level.

An 18 by 42-in. non-condensing engine runnng at 85 rev. per min. drives the exciters for all the generators. These are 125-volt, direct current, belt-driven machines.

The power plant also includes a 16 by 28-in. steam, 25¼ by 16¼-in. air, 16-in. stroke, cross compound air compressor, to supply air at 80 lb. pressure at the quarry and other parts of the works. The fuel used is a mixture of anthracite birdseye and bituminous slack coal burned with natural draught. The coal falls from the cars, in which it is received, into a hopper below the tracks. Through a gate in this hopper the coal passes to a transfer car, carrying it on a horizontal trestle over the storage bin and then to the boilers, a distance of about 200 ft. The firing is done by hand.

Ashes are removed by a dump-car running in a tunnel under the new boilers and at floor level in the old boiler room. The ash track is horizontal with the dump beside the creek.

The load of the power plant seldom varies more than 15 per cent. from a mean throughout the 24 hr., and the operation is often 365 days in the year.

THE CHATTANOOGA & TENNESSEE RIVER POWER COMPANY

THE CHATTANOOGA & TENNESSEE RIVER POWER COMPANY.

GENERAL.

The generating plant of the Chattanooga and Tennessee River Power Company is a water power station, located on the Tennessee River, at Hales Bar, about 33 miles below Chattanooga. The dam is designed for the double purpose of improving the navigation of the river and furnishing water power for the generation of electric energy. The hydraulic and mechanical work was in charge of Mr. John Bogart, C.E., consulting engineer of the Chattanooga and Tennessee River Power Company.

The dam is about 1200 ft. long and has an average height of about 52 ft. At the west end of the dam a lock, having a clear width of 60 ft., is provided for the convenience of navigation. The lock and dam are built of cyclopean concrete. The power station is situated at the east end of the dam. Running the full length of the dam is a passageway 2½ ft. wide by 6½ ft. high, connecting the power house and lock. The conductors for furnishing the electricity for operating the machinery of the lock and for lighting are carried through this passage way. Near the power house a sluiceway is provided in the dam to supply water to the lower pool, at times when none is passing over the dam or through the power house.

The power station is 66 ft. wide by 353 ft. long, and in two sections, an operating building one story high, 220 ft. long, and a switch and transformer house three stories high and 133 ft. long. The operating building consists of seven bays, each containing two turbine units, making a total of fourteen. Each unit consists of three turbines mounted on a vertical shaft with a generator at its upper end. Each generator has a capacity of 3000 kw., making a total capacity of 42,000 kw. for the station. Under ordinary stages of the river only two of the turbines will be used for each unit, the third being held in reserve and used when there is a large quantity of water flowing, but giving a reduced head due to back water in the tail race. The two lower turbine wheels are 72 in. in diameter, and the upper wheel 65 in. in diameter. The turbines run at 112½ rev. per min. Each unit is capable of delivering 5250 hp. with a head of 35 ft.

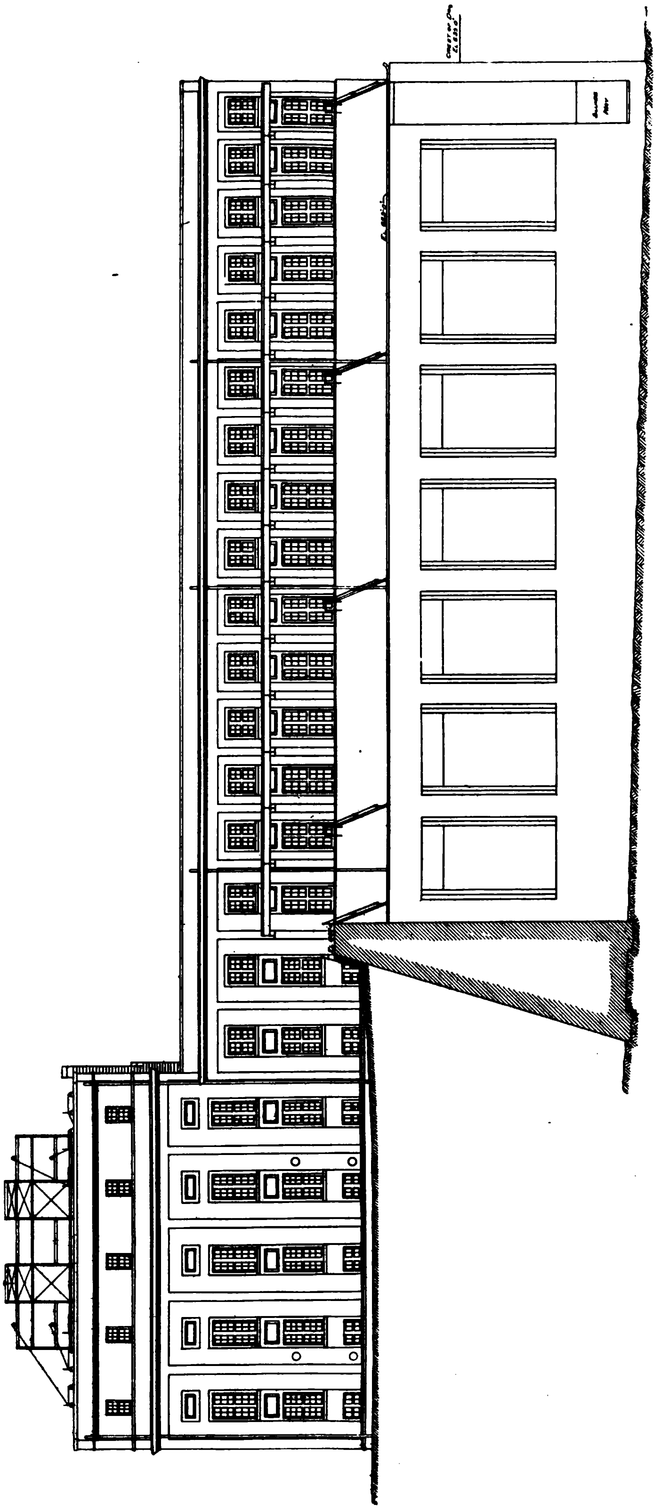


FIG. 102.—Up-Stream Elevation, Hales Bar Station, Chattanooga & Tennessee River Power Co.

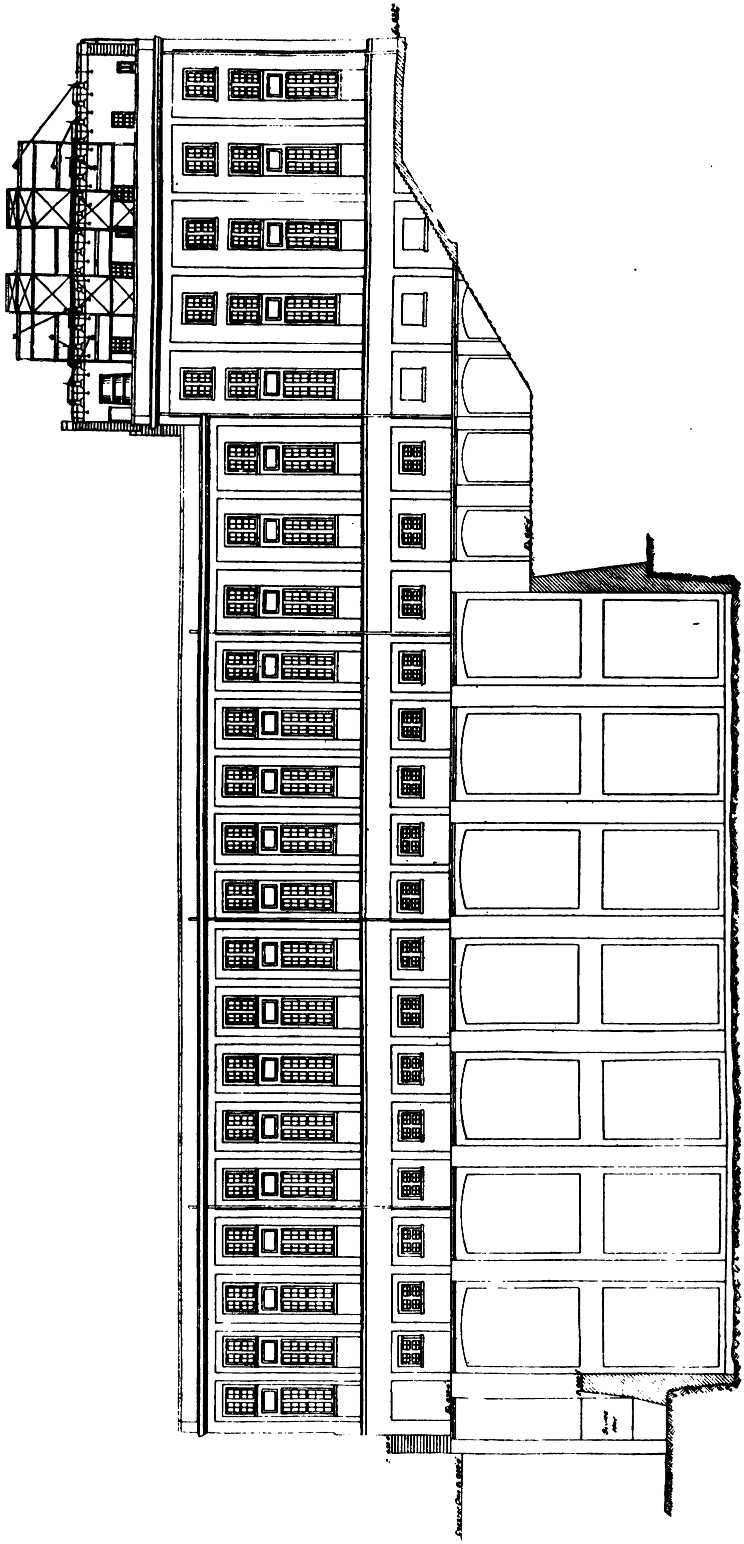


FIG. 103.—Down-Stream Elevation, Hales Bar Station, Chattanooga & Tennessee River Power Co.

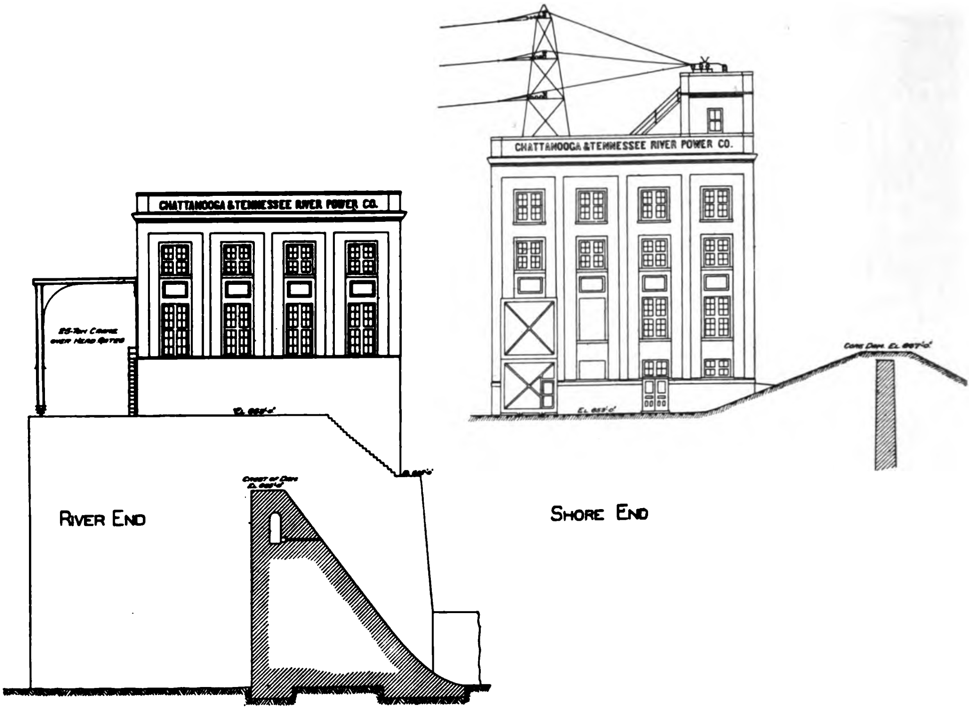


FIG. 104.—Elevations, Hales Bar Station, Chattanooga & Tennessee River Power Co.

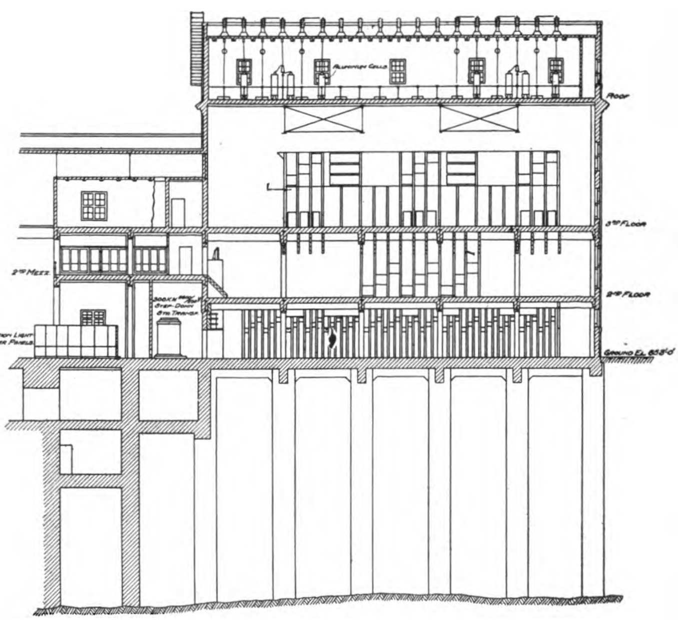


FIG. 105.—Longitudinal Section E-E, Hales Bar Station, Chattanooga & Tennessee River Power Co. (See Fig. 107).

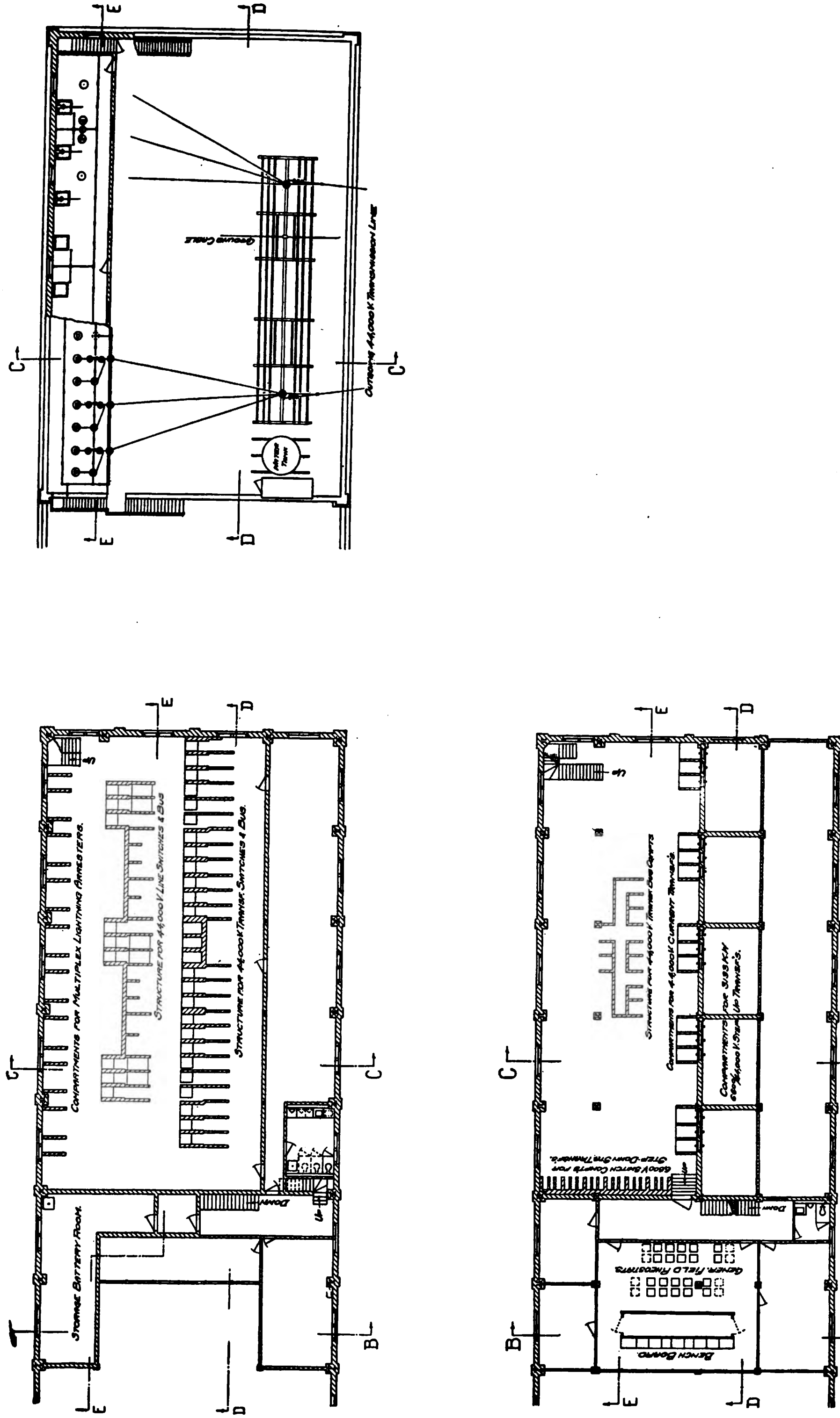


FIG. 106.—Second, Third Floor and Roof Plans, Hales Bar Station, Chattanooga & Tennessee River Power Co.

The operating building rests practically on the east end of the dam and is carried down to solid rock. The switch and transformer house is supported by round concrete piers carried down to solid rock. The piers were placed by means of light sheet steel caissons sunk through the earth to solid rock, the earth being excavated as the caissons were sunk; the steel caissons were filled with concrete, the concrete piers being proportioned so as to stand the entire load without any assistance from the light steel shell.

The operating building and the switch and transformer house are steel frame structures with concrete walls. The main floor of the transformer house is composed of reinforced concrete, and the upper floors and the roof of the transformer house and the roof of the operating building are built of flat concrete arches set between steel beams.

An electric traveling crane of 50 tons capacity is provided to handle the generator and turbines in the operating room, and a gantry crane is placed on the up-stream side of the operating building to handle the head gates.

ELECTRICAL INSTALLATION.

The electrical installation may be divided into three principal parts, viz: the generating station, the transmission line and the substation (transformer station).

THE GENERATING STATION.

This station is laid out to accommodate fourteen a. c. generators, six exciters, one exciter switchboard, one a. c. lighting and power board, one a. c. control board, fourteen a. c. generator field rheostats, one storage battery, six step-down transformers, fifteen step-up transformers, twenty-nine 6600-volt H3 oil circuit breakers and buses, ten 45,000-volt H3 oil circuit breakers and buses, three sets of multiplex lightning arresters and choke coils, and three sets of electrolytic lightning arresters and horn arresters.

With the exception of the storage battery all the above apparatus was manufactured by the General Electric Company and will be installed on the three floors and the roof of the generating station.

The 14 alternating current generators are located on the main floor of the operating room, arranged in two rows, seven in each row.

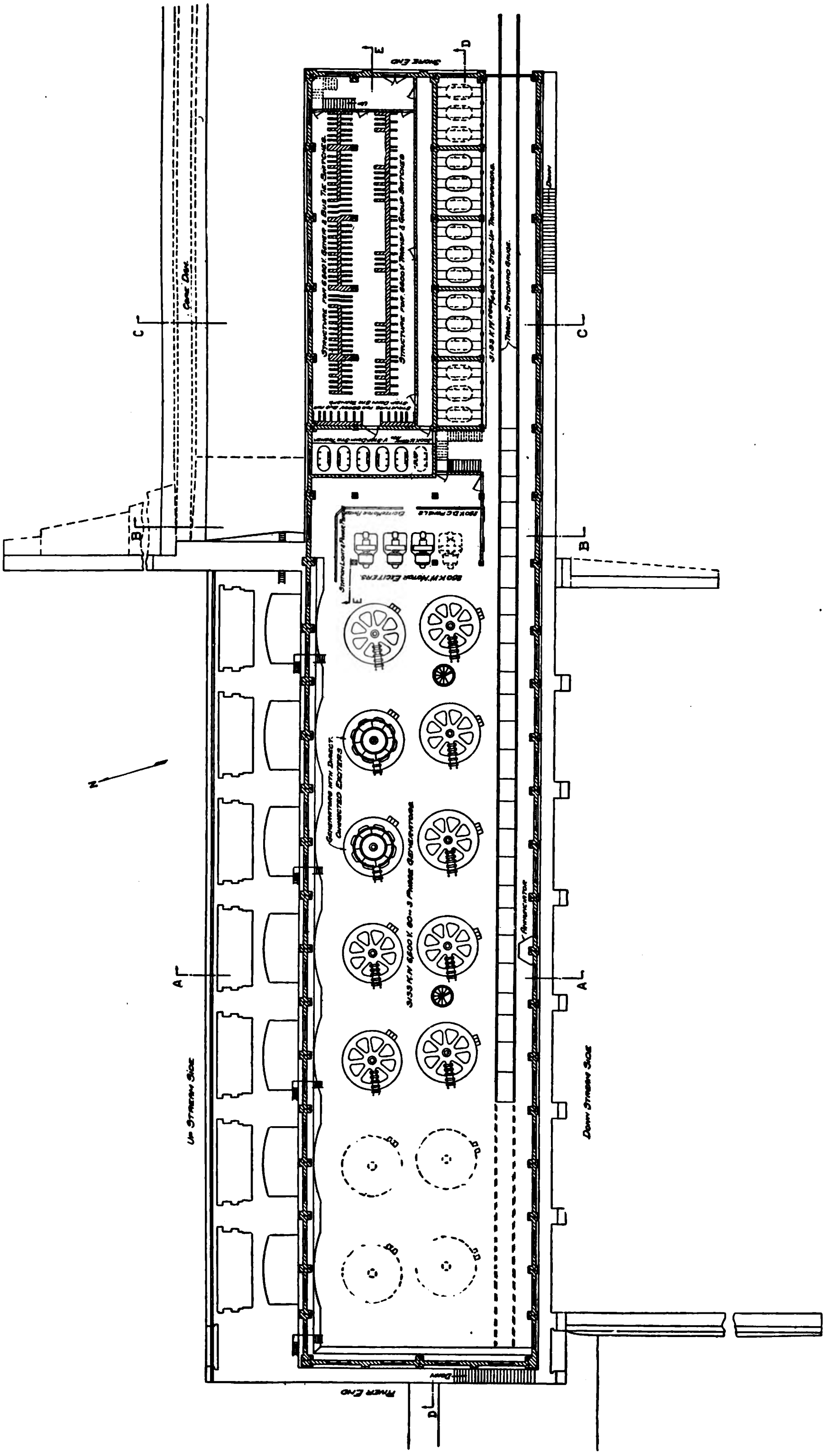


FIG. 107.—Main Floor Plan, Hales Bar Station, Chattanooga & Tennessee River Power Co.

Each generator is of 3000-kw. capacity, three-phase, 60 cycles, 6600 volts, 112.5 rev. per min., and is mounted on a vertical shaft, which is driven by three water wheels.

At present there will be installed only ten generators, two of which will have a 100-kw. exciter, mounted on the shaft.

On the main floor of the operating room, near the switchboard, are located the other four exciters, each consisting of a 250-kw., 250-volt, 720-rev. per min., direct current generator, driven by a 375-hp., 220-volt, 720-rev. per min., three-phase induction motor, both the generator and motor being mounted upon a common base and coupled together.

On the same floor, close to the motor-exciters, is located the exciter switchboard and the alternating current light and power board.

At the extreme eastern end of the main floor of the operating room are located six step-down transformers, each of 300-kw. capacity, three-phase, 60 cycles, 6600/230 volts, oil cooled. These step-down transformers are located in back of the alternating current light and power board, but are separated from it by a fire-proof enclosure.

At present only five step-down transformers will be installed, three of which will furnish alternating current to the exciter-motors and two will furnish current for the station lighting and power.

Above the exciter board and the step-down transformers is a gallery on which is located the main alternating current 6600 and 44,000-volt control switchboard, from which are also operated the alternating current generator field rheostats, located in the rear of the board.

From each of the alternating current generators, three single-conductor cables are run in bituminized fibre conduits, laid in concrete, to the generator oil circuit-breakers and generator buses, which are located in the north part of the first floor of the transformer house, divided from the operating house by a 12-in. thick concrete wall.

From the generator buses current is sent through oil circuit-breakers to the 15 step-up transformers, which are located on the first floor, but are separated from the switch room by a 12-in. concrete wall.

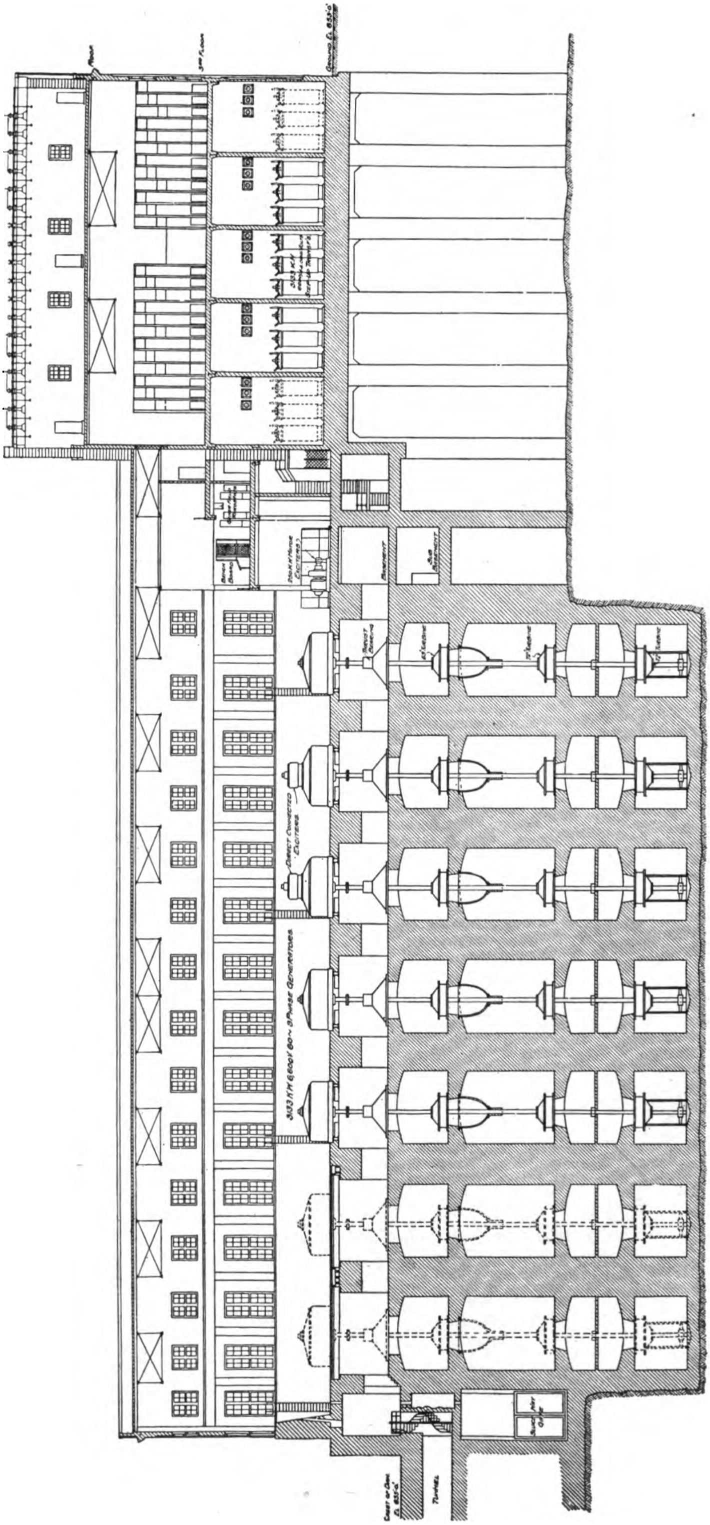


FIG. 108.—Longitudinal Section D-D, Hales Bar Station, Chattanooga & Tennessee River Power Co. (See Fig. 107.)

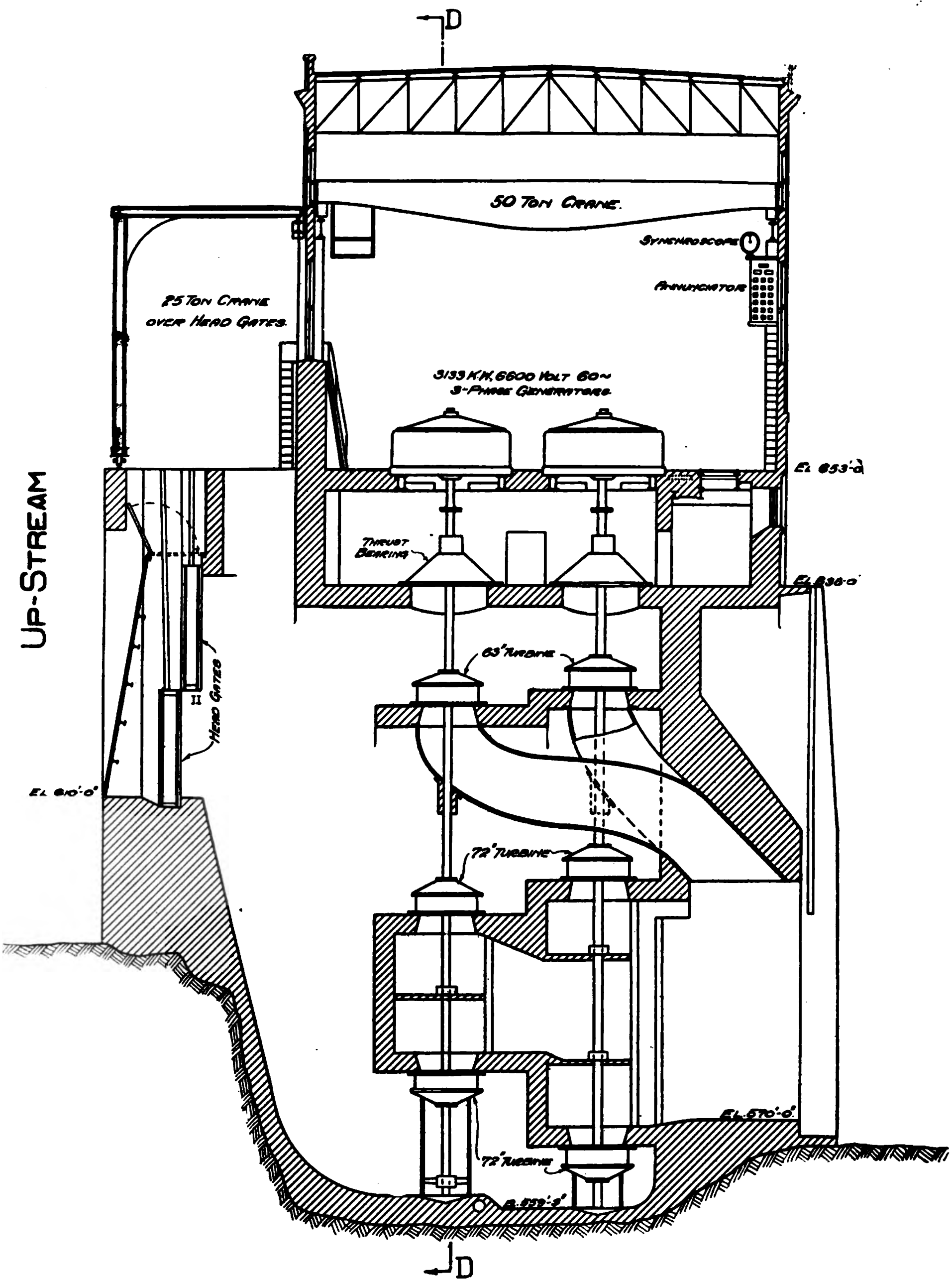


FIG. 109.—Cross Section A-A, Hales Bar Station, Chattanooga & Tennessee River Power Co. (See Fig. 107.)

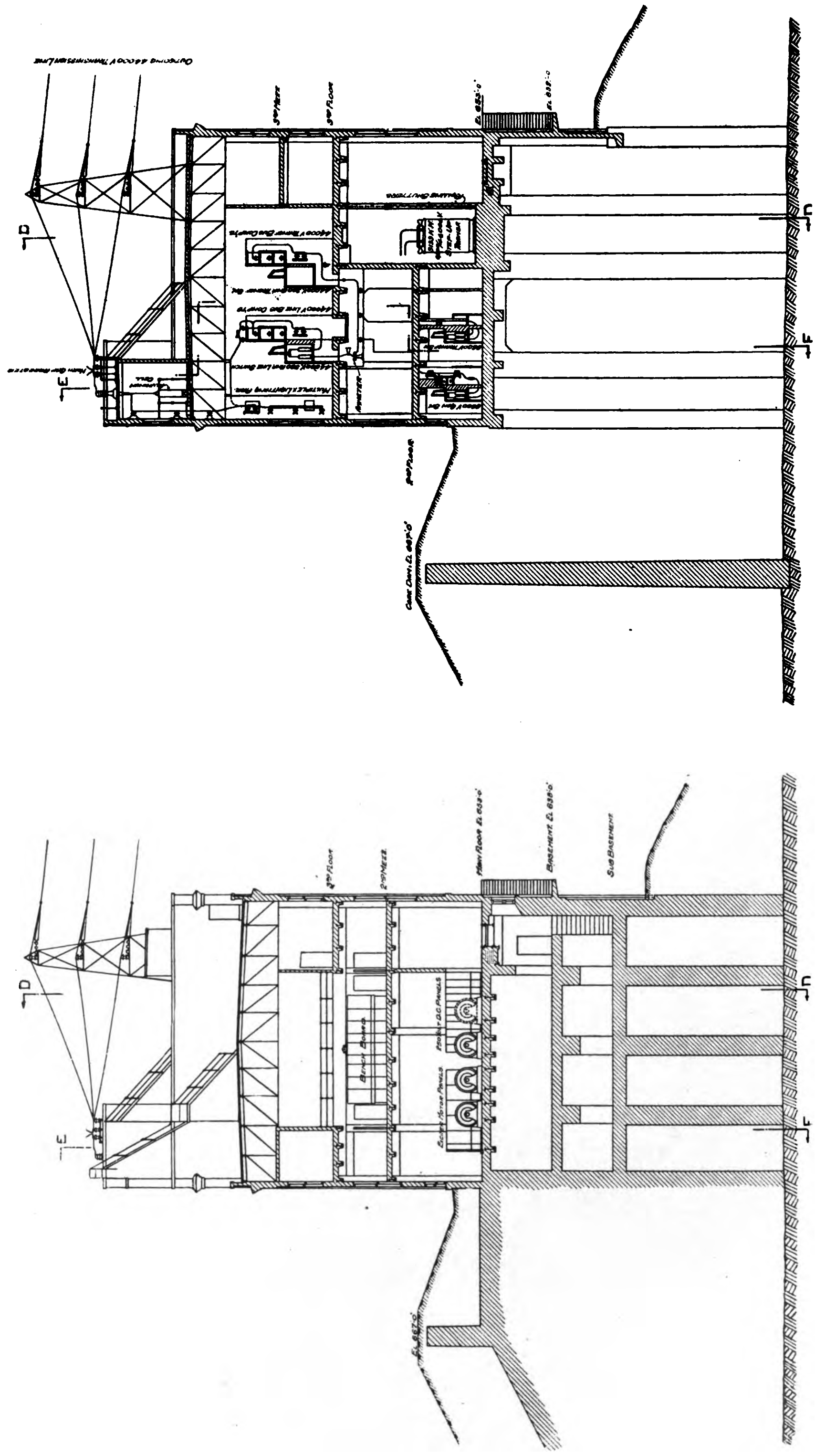


FIG. 110.—Cross Section B-B and C-C, Hales Bar Station, Chattanooga & Tennessee River Power Co. (See Fig. 107.)

The 15 step-up transformers are grouped in five sets, three transformers to each set, each transformer being 3133 kw. capacity, high-tension side 25,400/44,000, low-tension 6600 volts, 60 cycles, single-phase, water-cooled. At present only three sets will be installed.

The 44,000-volt current from the step-up transformers is transmitted through oil circuit-breakers to the 45-000-volt buses, which are located partly on the second and partly on the third floor in the transformer house. On this floor are also located the 44,000-volt multiplex lightning arresters.

From the 45,000-volt buses the current is sent through two oil circuit-breakers and choke coils up on to the roof, where connections are made with the two transmission lines, carried on a steel tower built on top of the roof. The ends of each line are connected to horn arresters, which are located on top of a narrow house or enclosure built on the roof. From the horn arresters connections are run through "roof entrance" type insulators to the electrolytic arresters, four to one line, which are located in the above enclosure.

There is provision made for a third (emergency) transmission line, which will not be installed at the present time.

All the H3 oil circuit-breakers and buses, both 6600 and 44,000 volts are installed in compartments built of reinforced concrete.

All the main 6600-volt connections are cables with 2/32-in. best rubber, 8/32-in. varnished cambric and two waxed braids. All 44,000-volt connections are bare copper tubing of 1-5/16-in. outside diameter. The connections between the horn and the electrolytic arresters are bare copper tubing of 15/16-in. outside diameter.

TRANSMISSION LINE.

The transmission lines leave the generating station on top of the roof at almost a right angle to the long side of the building, and are carried to the substation on 175 steel towers, exclusive of the two steel towers, one on top of the generating station and a similar tower on top of the substation.

The pins which support the large line insulators are of malleable iron, and are designed to withstand a horizontal strain of 6000 lb.

The strain insulators are furnished by the General Electric

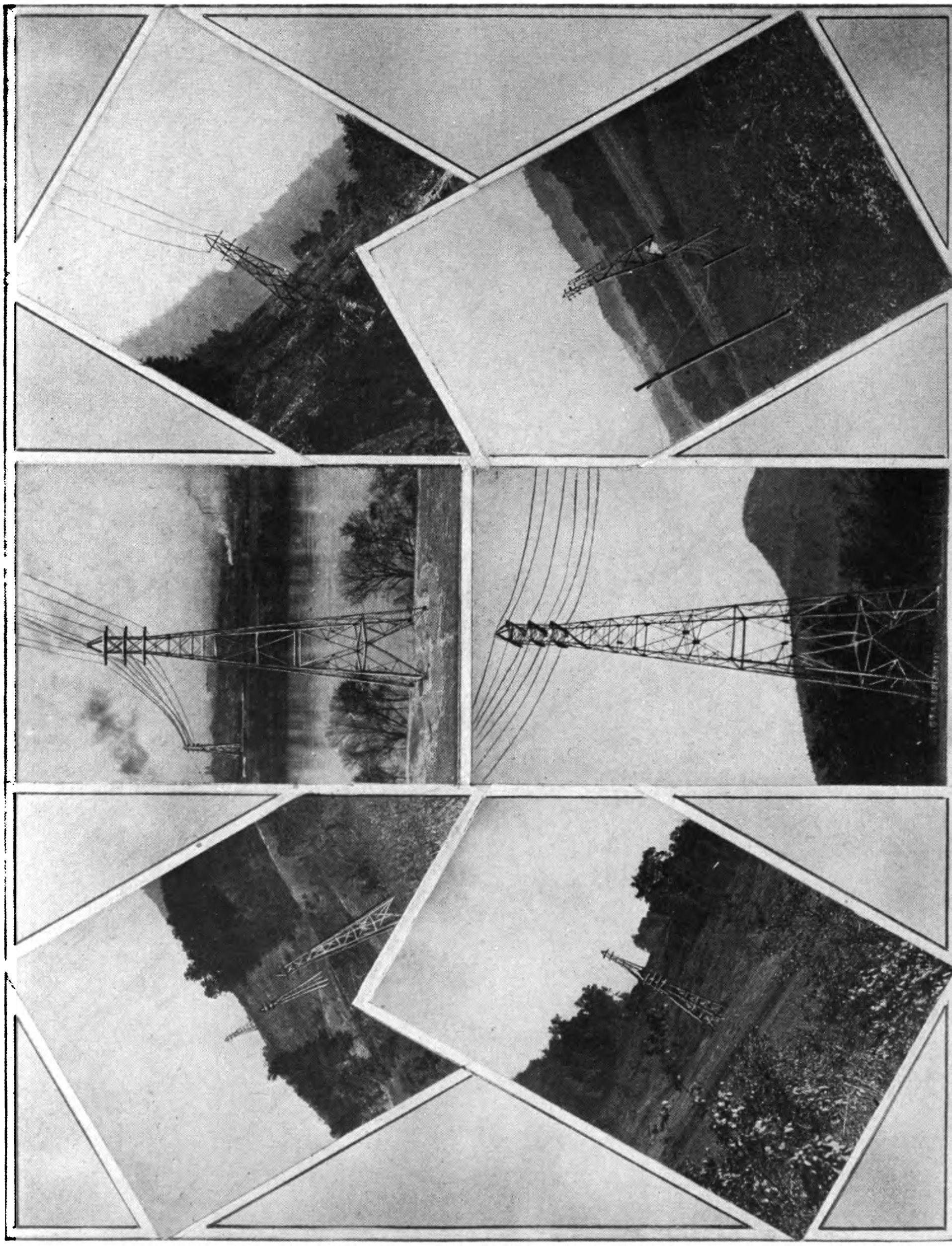


FIG. 111.—Transmission Lines, Chattanooga & Tennessee River Power Co.

Company and the line insulators by New Lexington Company. The transmission line follows, the greater part of its route, the tracks of the N. C. and St. Louis Railroad Company, crossing them in six places, and in one instance crossing the tracks of the proposed route of the Southern Railroad Company, quite close to the border of the State of Georgia. After going in an easterly direction about two-thirds of its total length it turns sharply north and continues in that direction until it reaches a point on the river near Moccasin Bend, where it turns north-east, crossing the Tennessee River and Moccasin Bend, and crossing the Tennessee River for the second time, enters the City of Chattanooga at the foot of Henry Street.

From the foot of Henry Street the transmission line follows the easterly course parallel with Henry Street until it reaches the substation at the northwest corner of Henry and Carter streets.

There are two transmission lines carried on steel towers, each tower carrying two lines, and each line consisting of three No. 000 bare copper cables, which are used on the whole distance of 17½ miles, with the exception of the two crossings over the Tennessee River, where 350,000-cir. mil bare copper cable is used.

On the top of the transmission towers a steel cable clamped to the steel structures with cast iron clamps is carried throughout the whole distance from the generating station to the substation with the exception of the two crossings over the Tennessee River. This steel cable is used as a ground wire.

The steel towers vary in height; 35-ft., 40-ft., 45-ft. and 60-ft. towers being used for ordinary spans and 150-ft. and 170-ft. towers being used for the river crossings.

Between the foot of Henry Street and the substation the transmission line crosses the N. C. and St. Louis Railroad Company tracks, and at each side of this crossing is erected a 60-ft. tower on concrete base 5 ft. high above the ground.

All the towers are erected on concrete foundations. On account of the mountainous character of the country it was not possible to have the towers located at equal distances, and, therefore, the spans vary between 200 and 700 ft., and in one instance the span being as short as 150 ft. The spans over the Tennessee River are 1400 ft. and 1500 ft. respectively. In several places it was necessary to erect angle towers, and on such the lines were dead ended.

THE SUBSTATION (TRANSFORMER STATION).

The substation is a three-story and basement building 69 ft. 10 in. long, 55 ft. 4 in. wide and 81 ft. 1 in. high from the ground, the basement being 15 ft. deep, and is located at the northwest corner of Henry and Carter Streets, Chattanooga, Tenn.

The substation is laid out to accommodate two sets of electrolytic lightning arresters and horn arresters, two sets of multiple lightning arresters and choke coils, five 40,000-volt H3 oil circuit breakers and buses, three 4000-volt H3 oil circuit-breakers and buses, one 40,000-volt control board, two 4000/2300-volt control boards, ten 2300-volt outgoing lighting feeders, fourteen 4000-volt outgoing power feeders, one station a.c. light and power board, one motor generator set, three 2300/115-volt oil-cooled step-down transformers for station light and power, one storage battery, and nine 40,000/4000-volt main step-down transformers.

With the exception of the storage battery all apparatus is of the same type as that in the generating station.

The principal arrangement of the apparatus is similar to that in the generating station.

On top of the roof of the substation is a steel tower on which are supported the two transmission lines, which enter the building through an enclosure built on the roof, and through large openings in the roof enter the southern part of the third floor, where the 40,000-volt oil circuit-breakers and buses are located. On this floor, near the southern wall, are also installed the multiplex lightning arresters.

The ends of each line are connected to horn arresters, which are located on top of the enclosure, built on the roof. From the horn arresters connections are run through "roof entrance" type insulators to the electrolytic arresters, four to each line, which are located in the above enclosure.

From the buses, on the third floor, copper connections lead down to the southern part of the second floor, where two 40,000-volt transformer oil circuit-breakers are located, and from which cables are run in fiber conduits to two banks of large step-down transformers, located in the middle part of the first (main floor). There are three large compartments built, each to accommodate three 3133-kw. water-cooled, single-phase, 60-cycle, 40,000/4000-

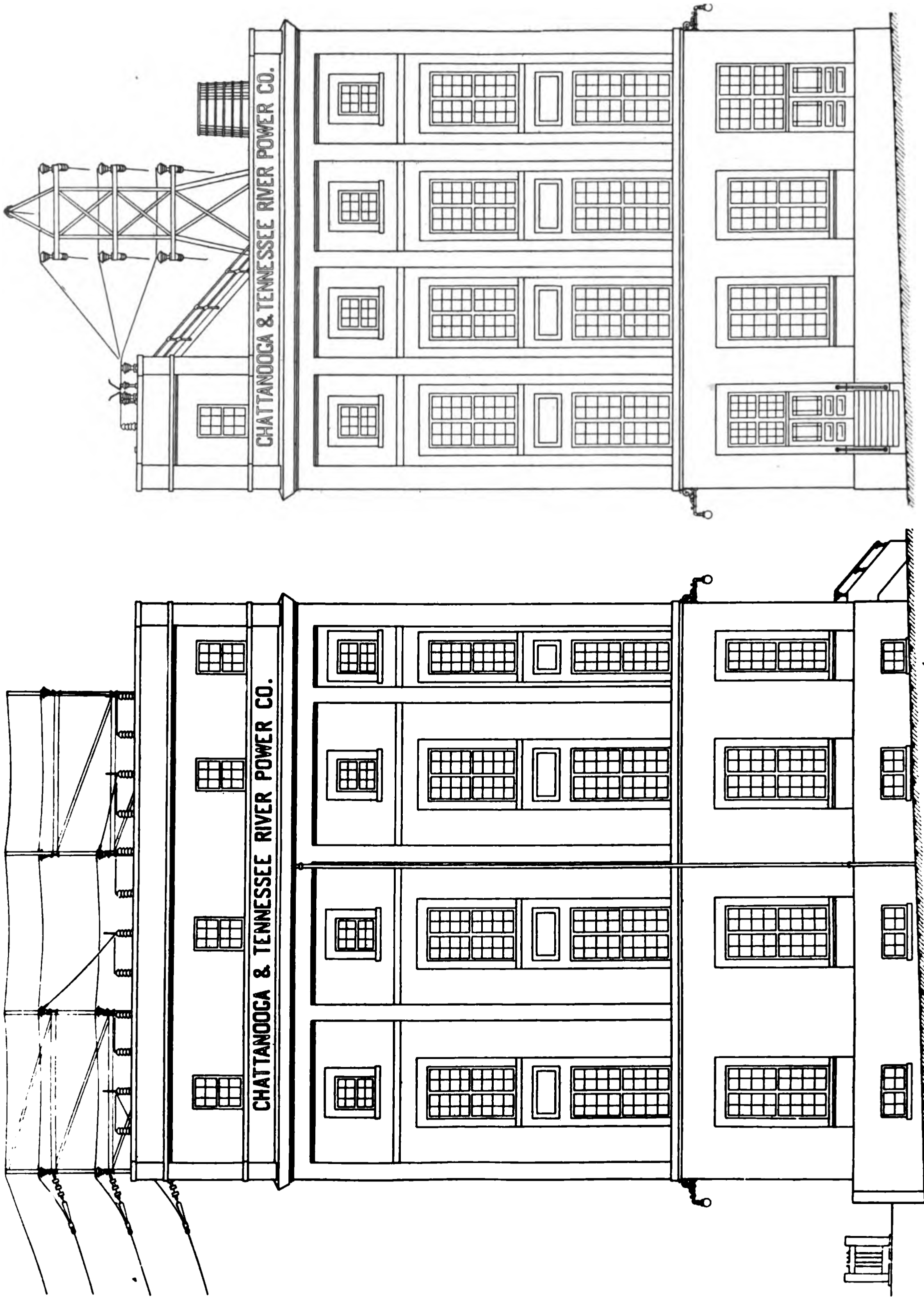
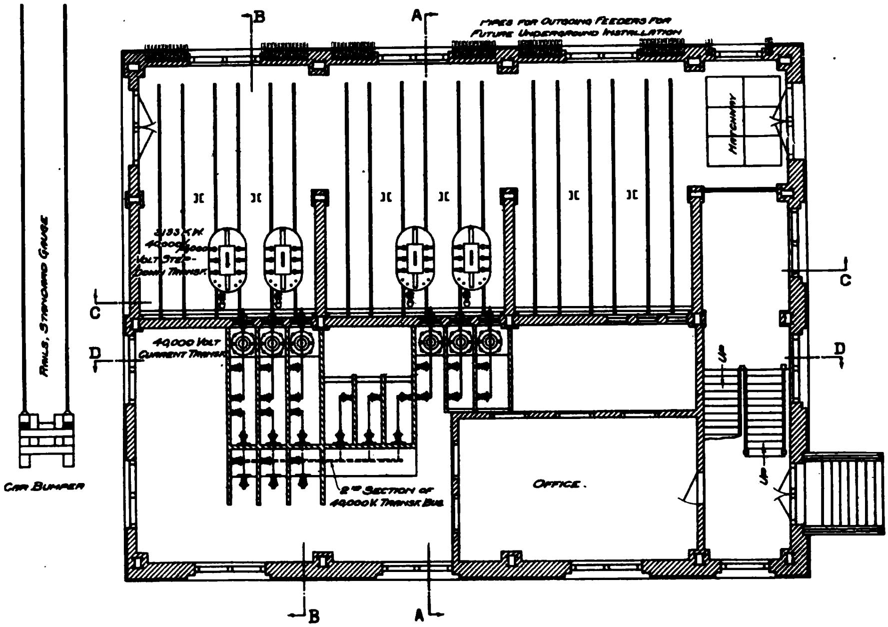


Fig. 112.—South and East Elevations, Substation, Chattanooga & Tennessee River Power Co.



. FIG. 113.—First Floor Plan, Substation, Chattanooga & Tennessee River Power Co.

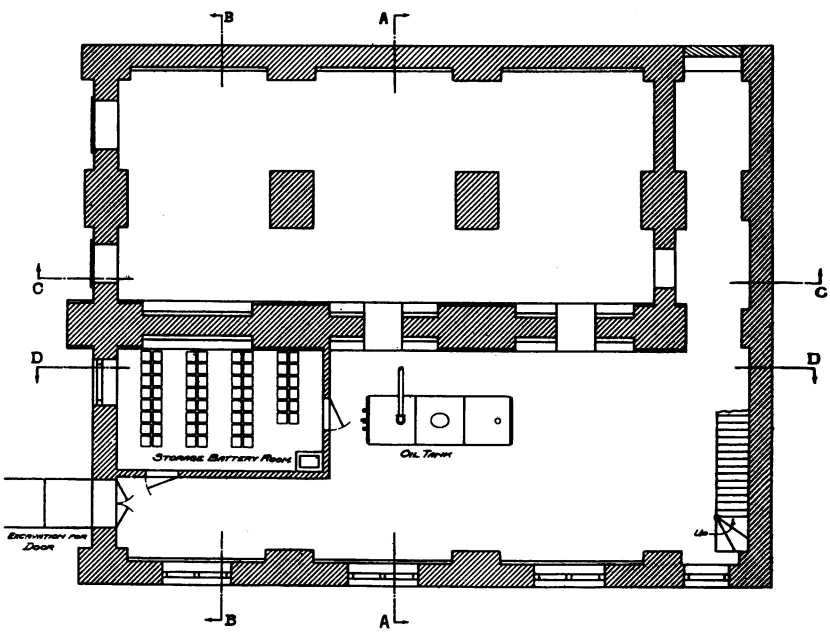


FIG. 114.—Basement Floor Plan, Substation, Chattanooga & Tennessee River Power Co.

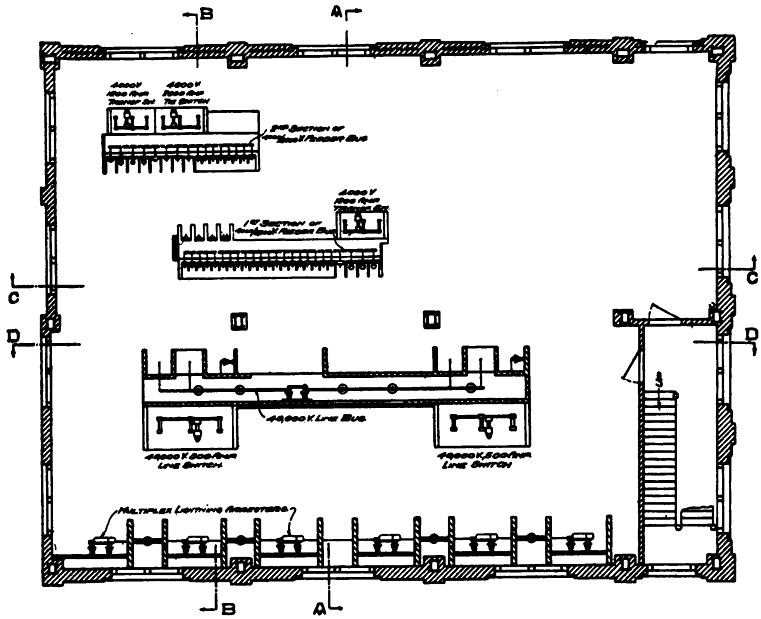


FIG. 115.—Third Floor Plan, Substation, Chattanooga & Tennessee River Power Co.

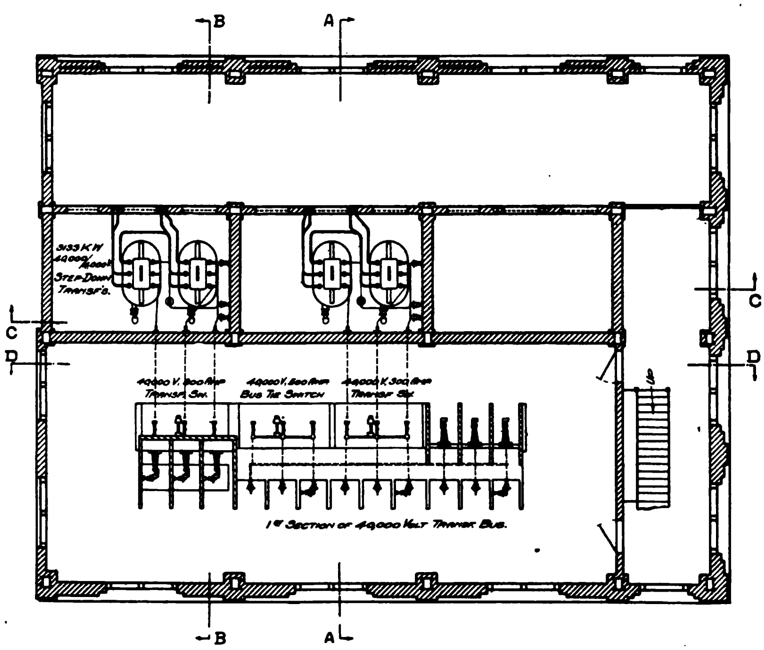


FIG. 116.—Second Floor Plan, Substation, Chattanooga & Tennessee River Power Co.

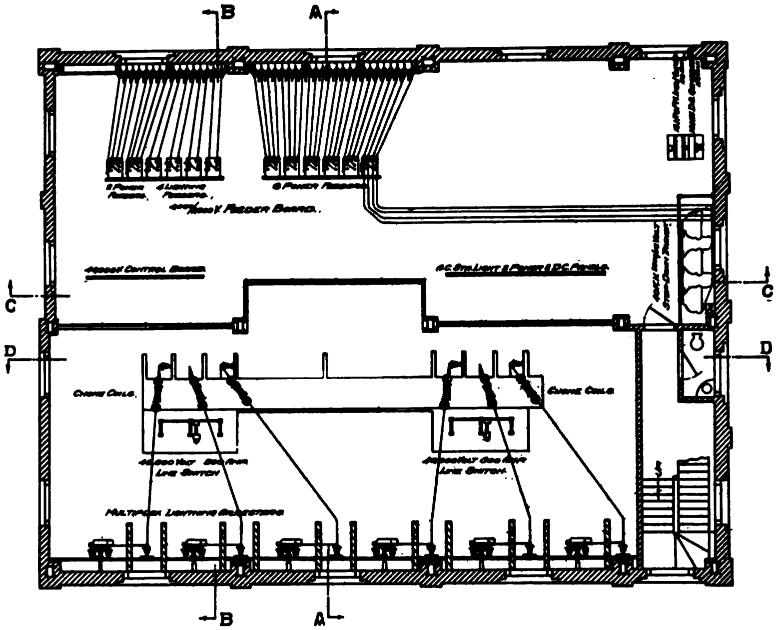


FIG. 117.—Gallery Floor Plan, Substation, Chattanooga & Tennessee River Power Co.

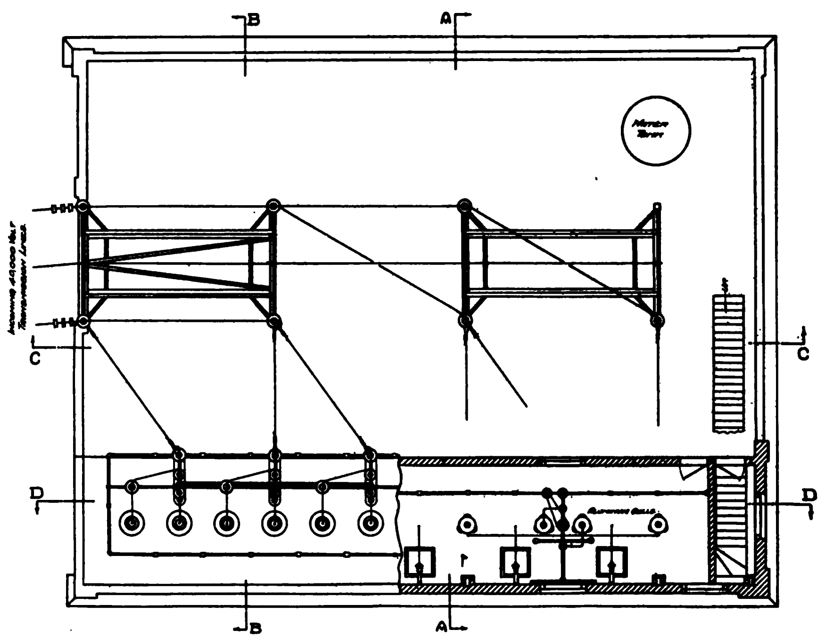


FIG. 118.—Roof Plan, Substation, Chattanooga & Tennessee River Power Co.

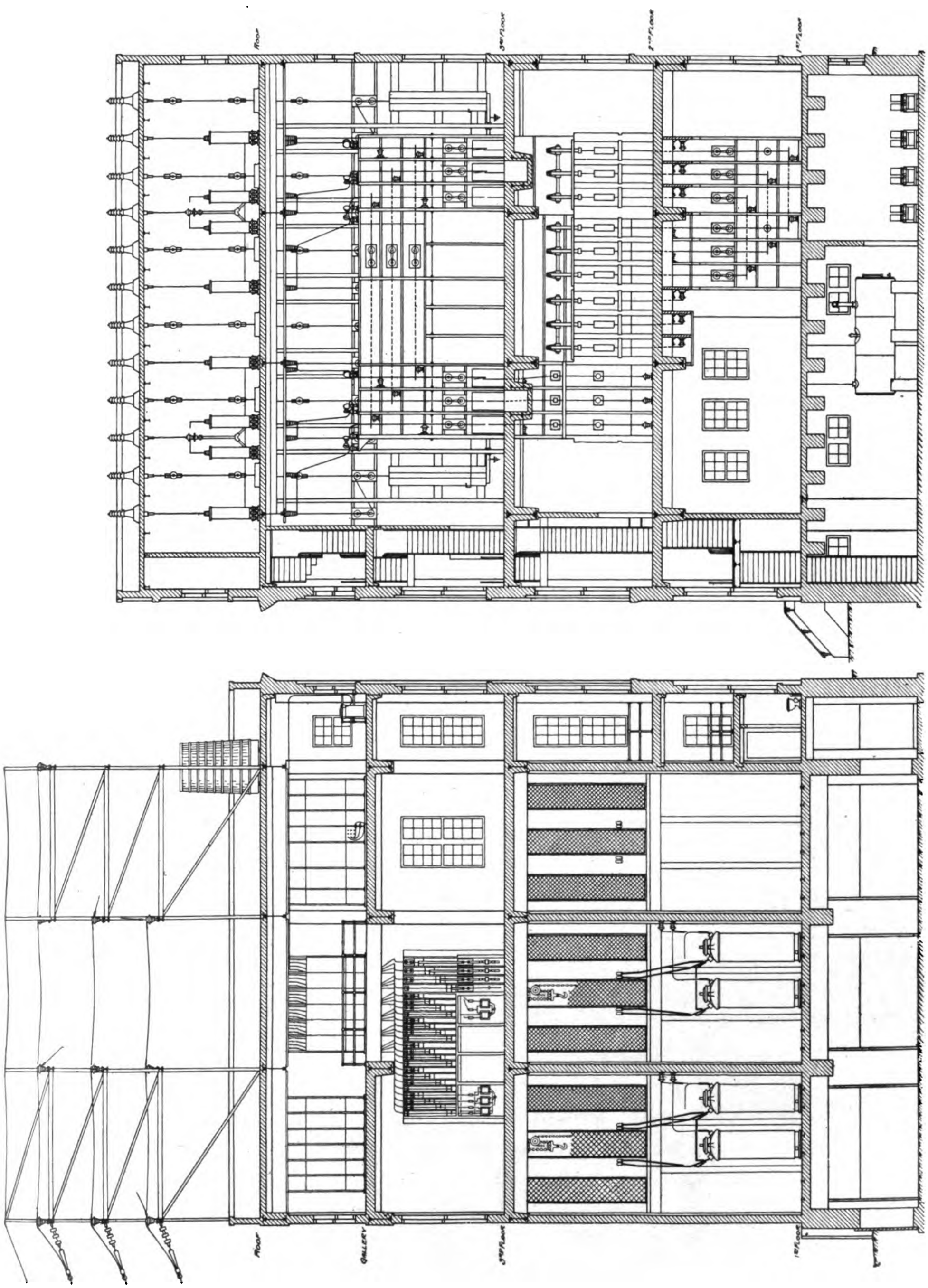


FIG. 119.—Longitudinal Sections C-C and D-D, Substation, Chattanooga & Tennessee River Power Co.

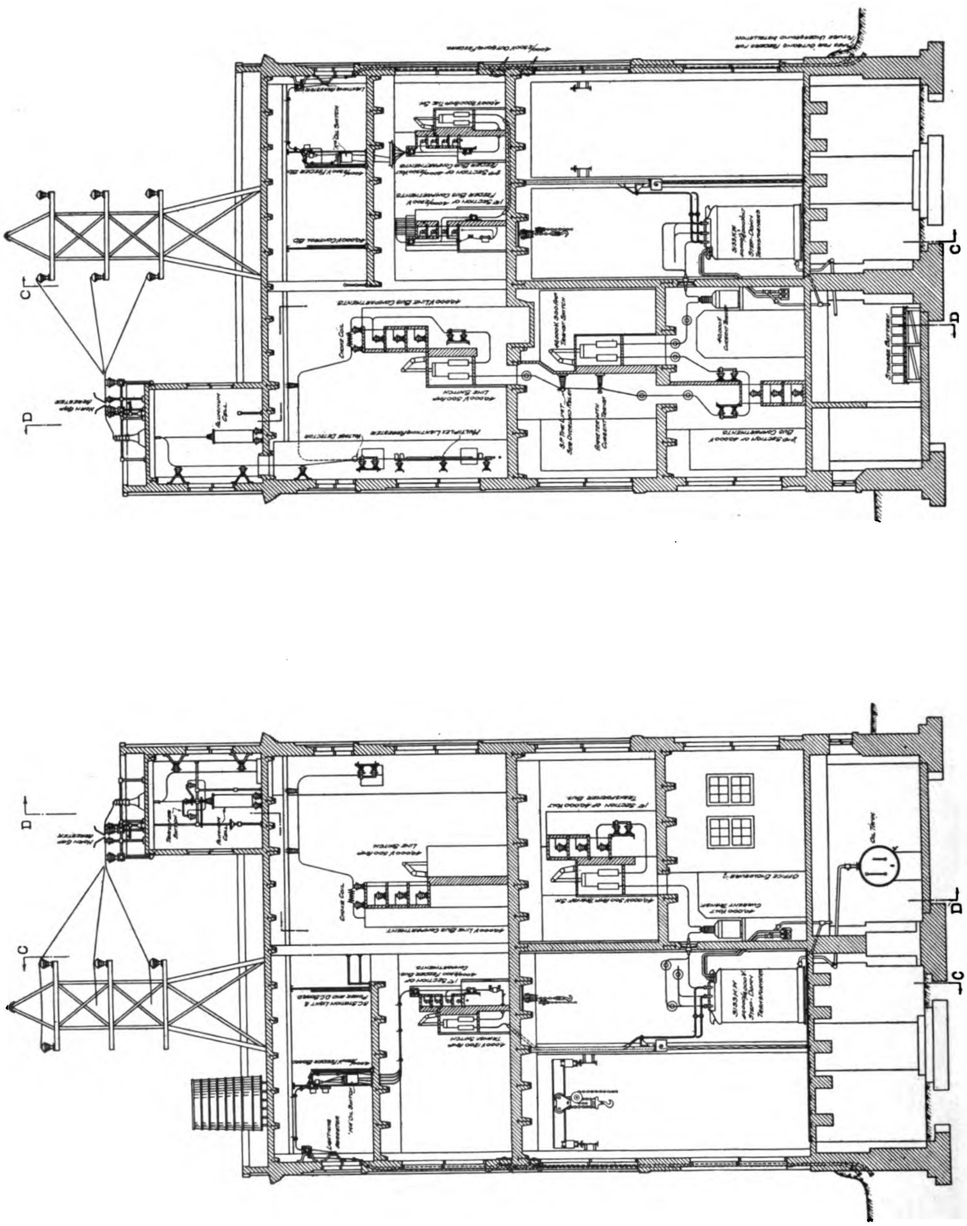


FIG. 120.—Cross Sections A-A and B-B, Substation, Chattanooga & Tennessee River Power Co.

volt transformers. At the present time only two sets of transformers, two in a set, will be installed. From the step-down transformers the 4000-volt current is carried through large cables in fiber conduits, built in concrete walls, up to the northern part of the third floor, where the 4000-volt transformer oil circuit-breakers and buses are located. From these buses leads are run upward to K4 automatic oil switches, which are mounted in the rear of the 4000/2300-volt board, located on a gallery called the third mezzanine floor. From this board circuits are run through choke coils out of the building, connections being made with multiplex lightning arresters, before leaving the building. As above mentioned, provision is made for ten lighting and fourteen power circuits, but at present only four lighting and eight power circuits will be installed.

On the third mezzanine are also located the main alternating current control board, from which are controlled all 40,000-volt and 4000-volt H3 oil circuit-breakers; one motor generator set, station light and power board, and three step-down transformers. The motor generator set consists of a 10-kw. 120-volt direct current generator direct-connected to a 15-hp. 115-volt three-phase induction motor. This motor generator will furnish the direct current for operating the oil circuit-breakers, but will be also used for charging the storage battery, which is located in the basement. Each of the three step-down transformers is 40-kw. single-phase, 2300/115 volts, oil-cooled.

Both the motor-generator and the storage battery and also the three station light and power transformers are controlled from the station light and power board.

At present all outgoing 4000 and 2300-volt leads will leave the building on the level with the third floor and will be supported on wooden poles erected on the sidewalks.

Provision is made for carrying the outgoing feeders in underground ducts, and for this purpose fiber conduits are built in the northern building wall and leave the same a short distance below the grade, being at present provided with fiber caps.

As in the generating station all the H3 oil circuit-breakers and buses are enclosed in concrete compartments.

All the 40,000-volt connections are bare copper tubing of 1-5/16-in. outside diameter, and all connections between the horn and the electrolytic arresters are bare copper tubing of 15/16-in. diameter.

All the 4000-volt connections are cables with 3/32-in. best rubber, 4/32-in. varnished cambric insulation and two waxed braids.

GOLD STREET POWER STATION
OF THE
KINGS COUNTY ELECTRIC LIGHT
AND POWER COMPANY

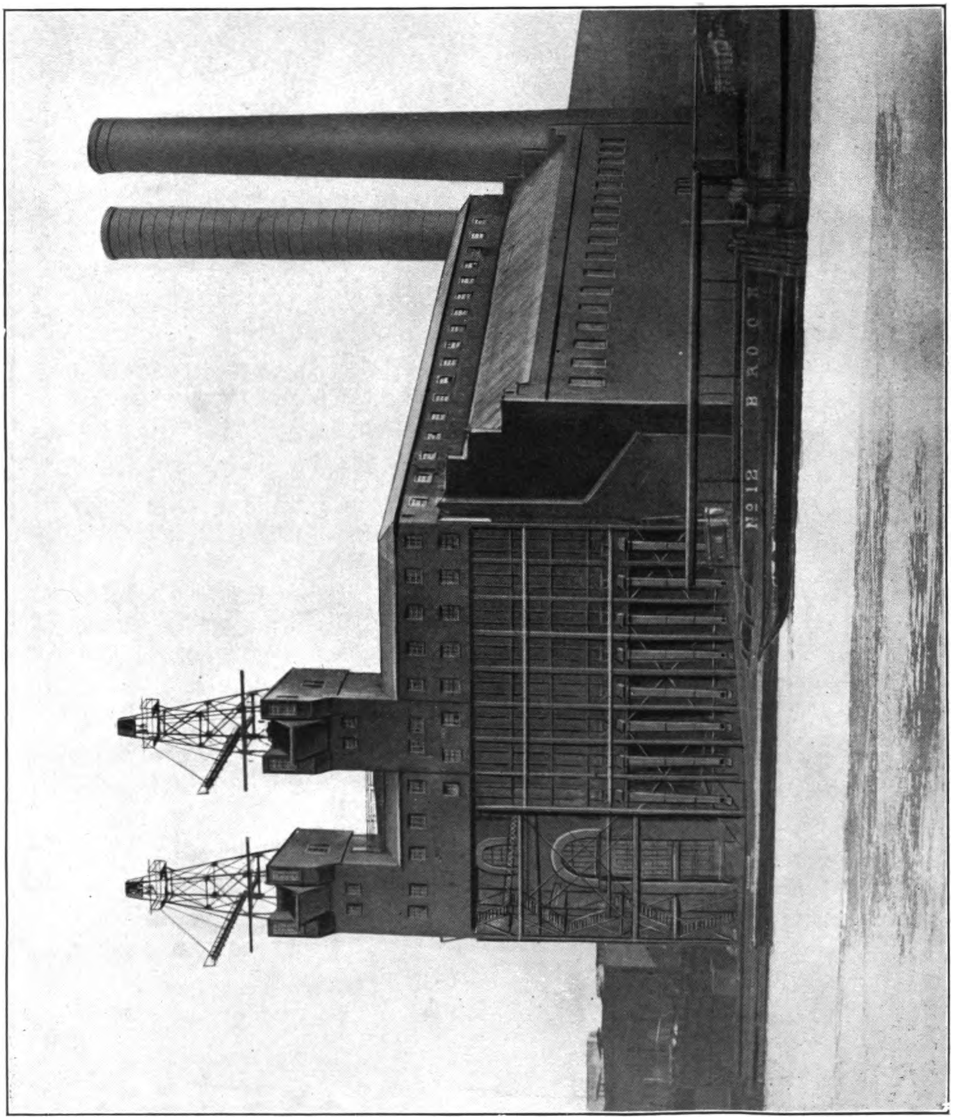


FIG. 121.—General View, Gold Street Station.

GOLD STREET STATION OF THE KINGS COUNTY ELECTRIC LIGHT AND POWER COMPANY.

GENERAL.

The Gold street station of the Kings County Electric Light and Power Company, operated by the Edison Electric Illuminating Company of Brooklyn, is situated on a piece of property roughly 415 ft. by 160 ft. at the intersection of Gold and John streets, Brooklyn. The plot runs from John street to the river bulkhead on the west side of Gold street. The present building does not occupy the entire lot, being placed at the river end and running the full width of the property. Between this building and John street there remains a space roughly 160 ft. square which is a reserve for future boiler-house additions.

The building is of steel frame construction, the columns resting on piling capped with concrete, and is irregular in shape, consisting of a rectangular boiler house, 170 ft. long by 63 ft. 10½ in. wide and the operating room, which is trapezoidal in shape. The latter has a frontage of 210 ft. on Gold street, and is 220 ft. long on the division wall side, by 95 ft. 10 in. wide.

The original installation consisted of six Stirling boilers of 500 hp. capacity each, equipped with under-feed stokers, and four 1000-hp. cross-compound horizontal Reynolds-Corliss engines driving 750-kw. Westinghouse three-phase alternators direct connected, at 94 rev. per min. Later, however, the growth of the system and the demand for greater output from Gold street resulted in a complete change in the power layout in order to economize space and at the same time greatly increase the capacity of the station.

STEAM PLANT AND GENERATORS.

It was decided to install turbines as the prime movers, and to replace the boilers with larger units, at the same time increasing the number of boilers to sixteen. Accordingly the engines and the original boilers were discarded and the present outfit substituted.

This consists of sixteen 750-hp. Babcock & Wilcox type boil-

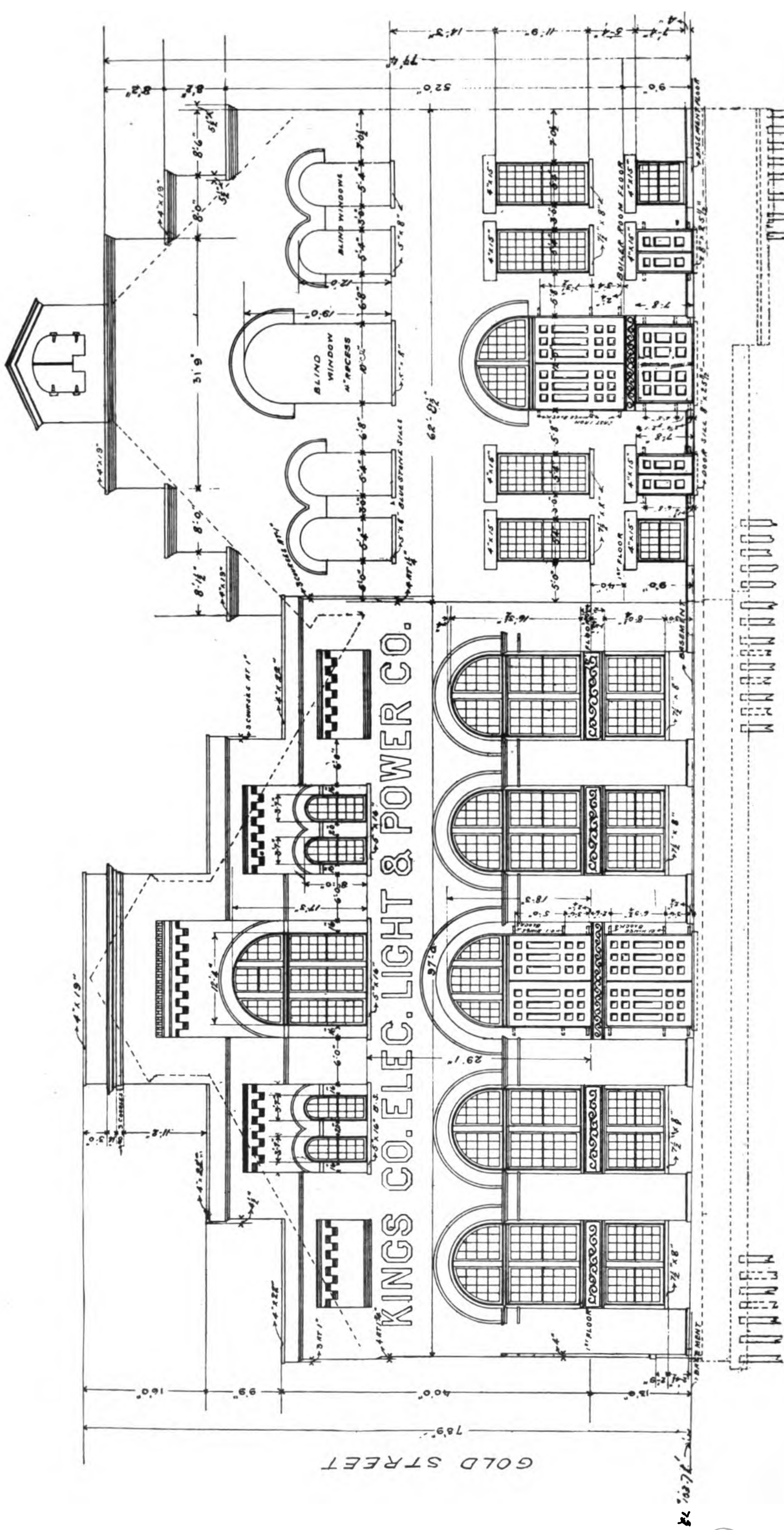


FIG. 122.—Elevation, River End, Gold Street Station.

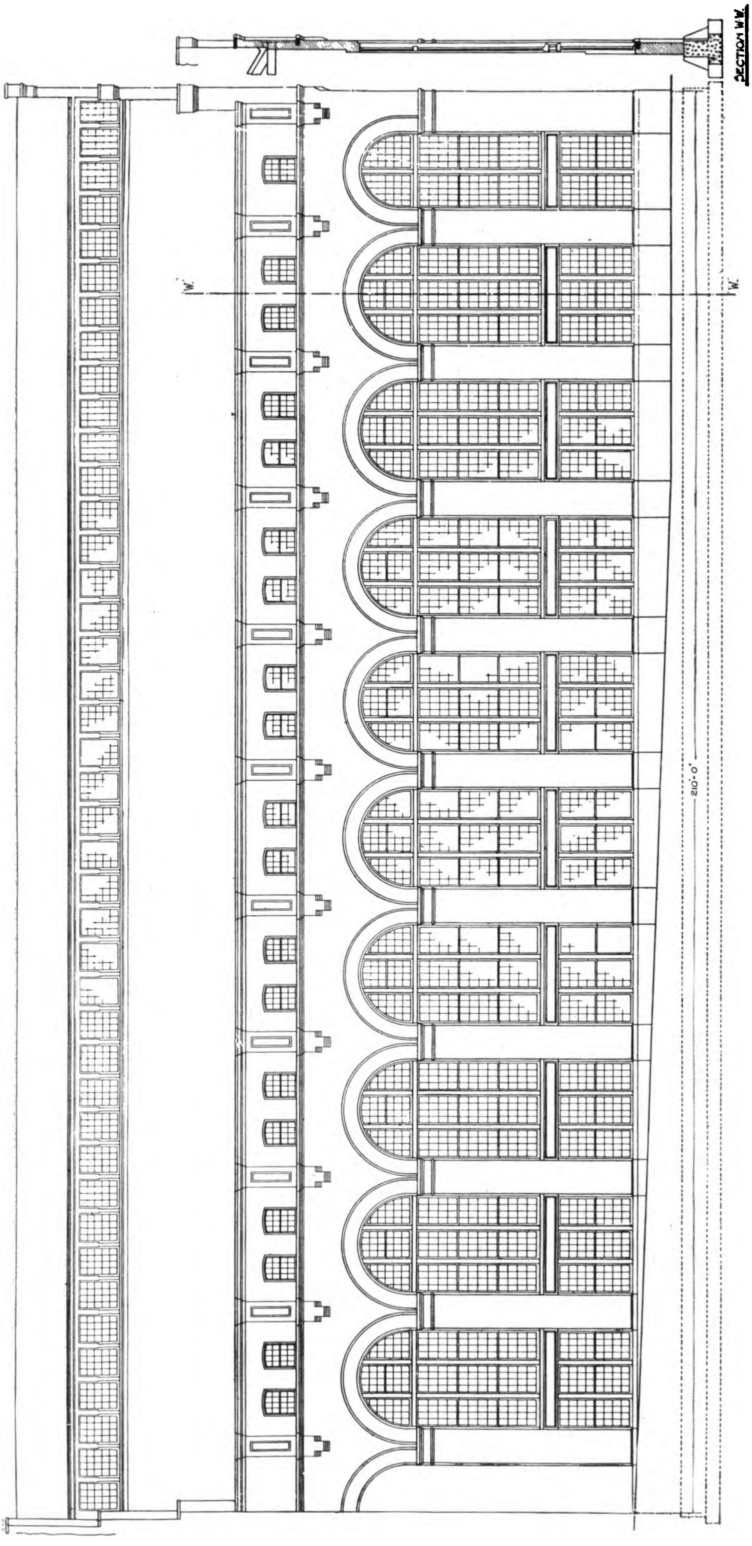


FIG. 123.—Elevation, Gold Street Front, Gold Street Station.

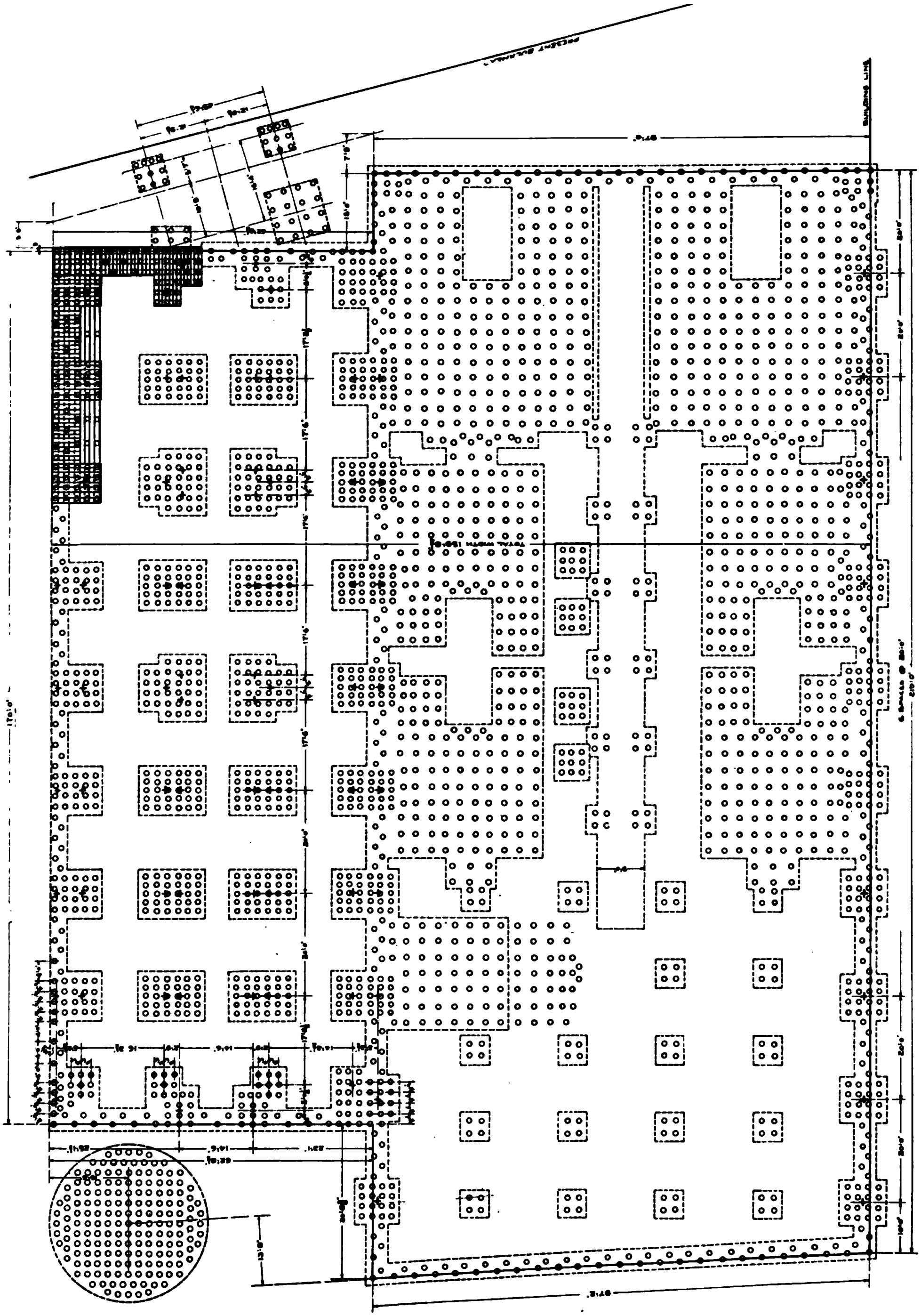


FIG. 124.—Foundation Plan, Gold Street Station.

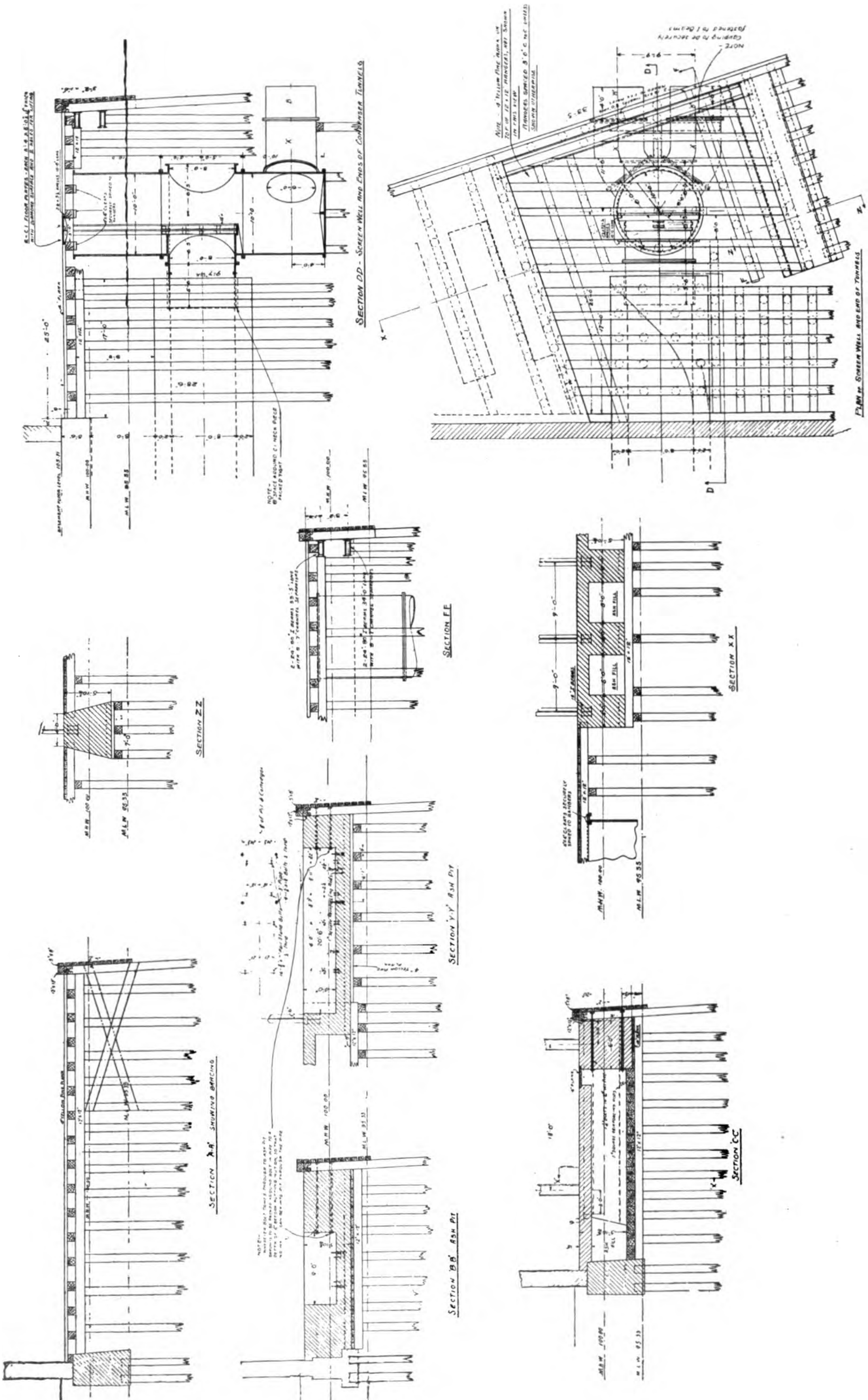


FIG. 125.—Details of Bulkhead Wall, Gold Street Station.

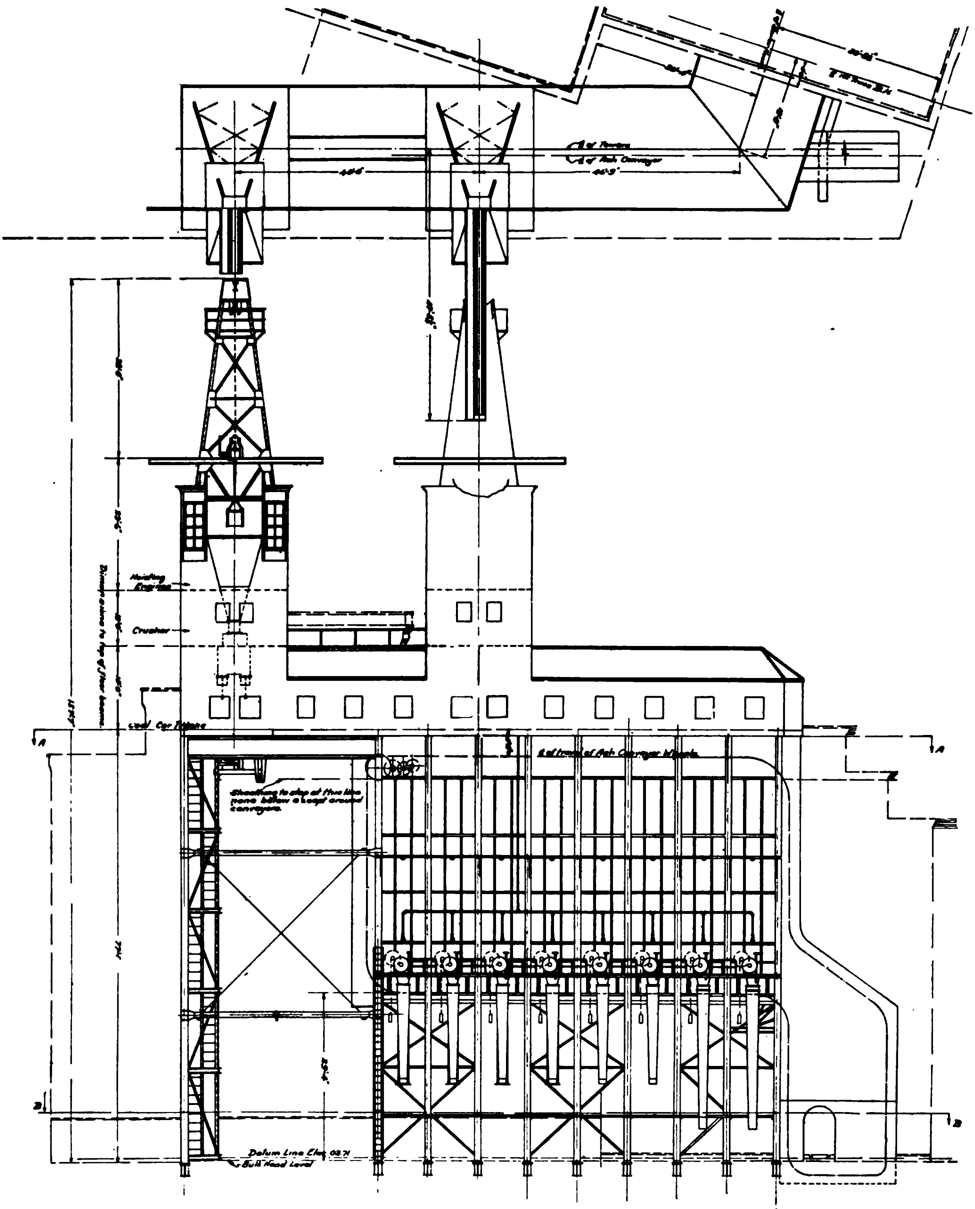


FIG. 126.—Elevation and Plan of Coal Towers and Ash Pocket, Gold Street Station.

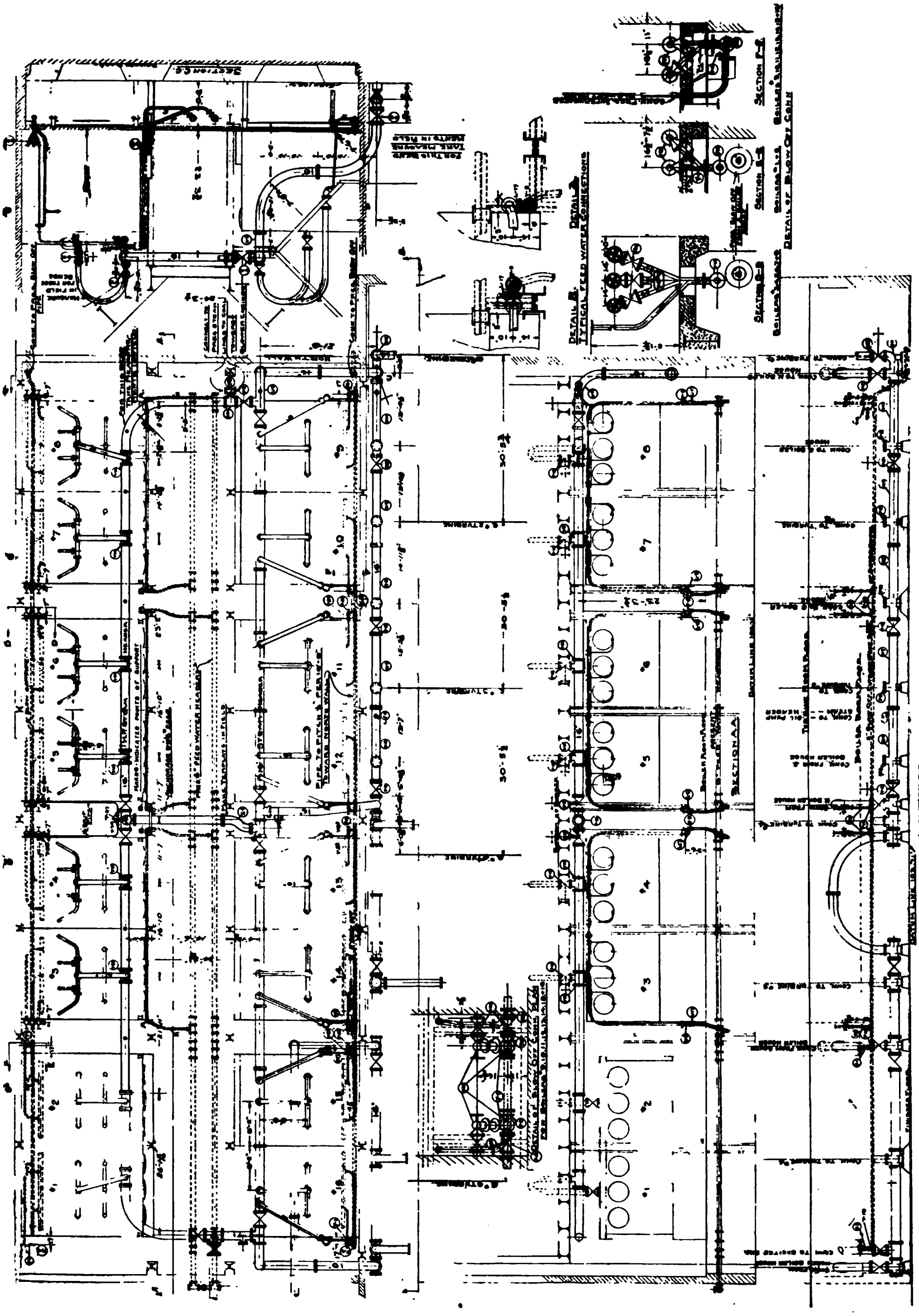


FIG. 127.—Plan and Elevation of High-Pressure Steam Feed and Blow-Off Piping, Gold Street Station.

ers, arranged on opposite sides of a single firing aisle, which runs lengthwise of the boiler house, one vertical and three horizontal steam turbines with an aggregate maximum output of 40,000 kw. with provision for two more units not yet installed. It has furthermore been provided to extend the operating room to include two more turbines, making a total of eight machines. As already mentioned space has been left for an auxiliary boiler house to take care of the additional turbines, so that the ultimate capacity of the station will be about twice its present output or 80,000 kw.

As arranged at present the three horizontal turbines are placed across the operating room at the south end, and the vertical machine is at the extreme northern end, a space being left between for the two additional units referred to above. These machines all take steam at 180 lb. per sq. in. and 100 deg. superheat and exhaust at 29 in. vacuum. The vertical unit is of 9000 kw. capacity, five-stage, 750 rev. per min. and drives a three-phase, 25-cycle, revolving field generator, producing current at 6600 volts. The horizontal turbines have respectively the capacities 6250, 9000 and 9375 kw. and are direct connected to generators of the same type as the vertical turbine.

The boilers are hand-fired, No. 3 buckwheat coal being used except on the peak, when soft coal is added. All the boilers are equipped with forced draft supplied by a duct under the boiler fronts.

There are two stacks set outside the boiler house, at the southern end. One is of brick, 13 ft. inside diameter and 160 ft. high above the grates. The second and newer stack is of concrete, 13 ft. 6 in. inside diameter and of the same height as its fellow.

The main boiler room header is of the ring type and composed of 16-in. cast steel pipe throughout. Three 16-in. mains lead from this header to the operating room header, which runs along the division wall below the operating room floor and is also made up of 16-in cast steel pipe. The turbine leads go up to the turbine throttles from this header and have no separators, the vertical leads themselves acting as separators. These leads are 14-in. pipe in the case of the two first horizontal turbines and 12-in. for the third horizontal and for the vertical machine. The

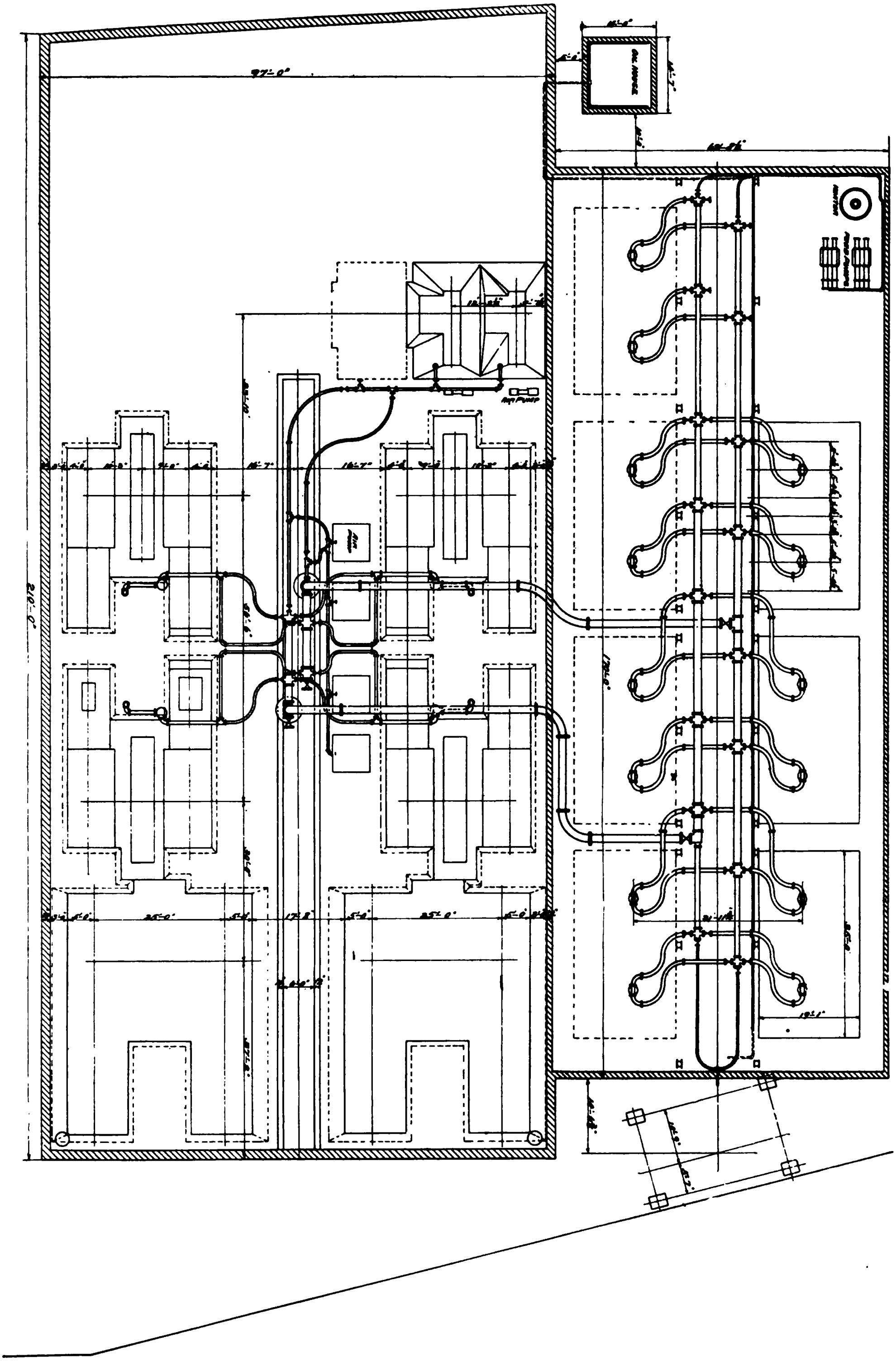


Fig. 128.—General Plan, Showing First Installation, Gold Street Station.

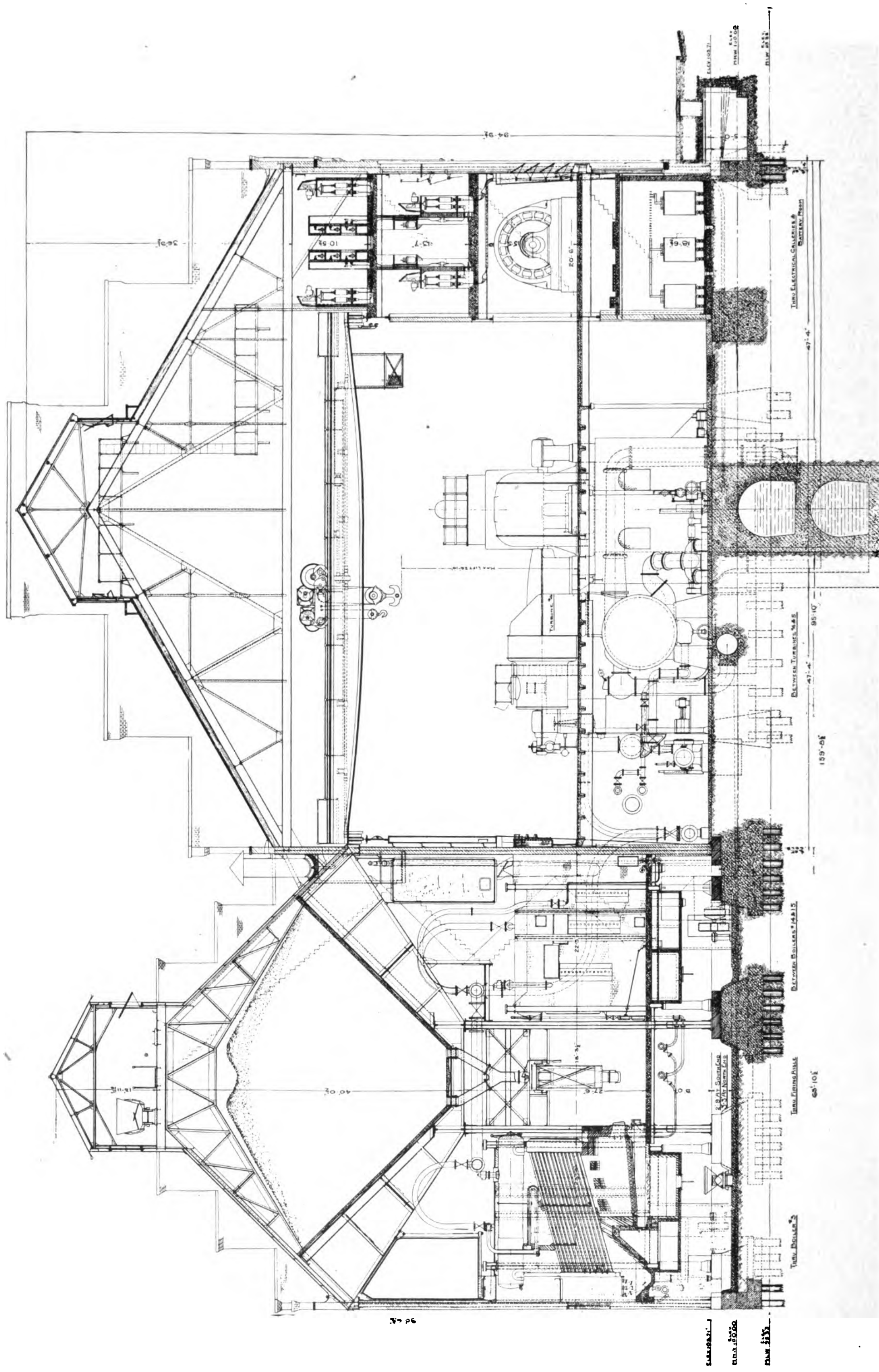


FIG. 129.—Cross-Section, Gold Street Station.

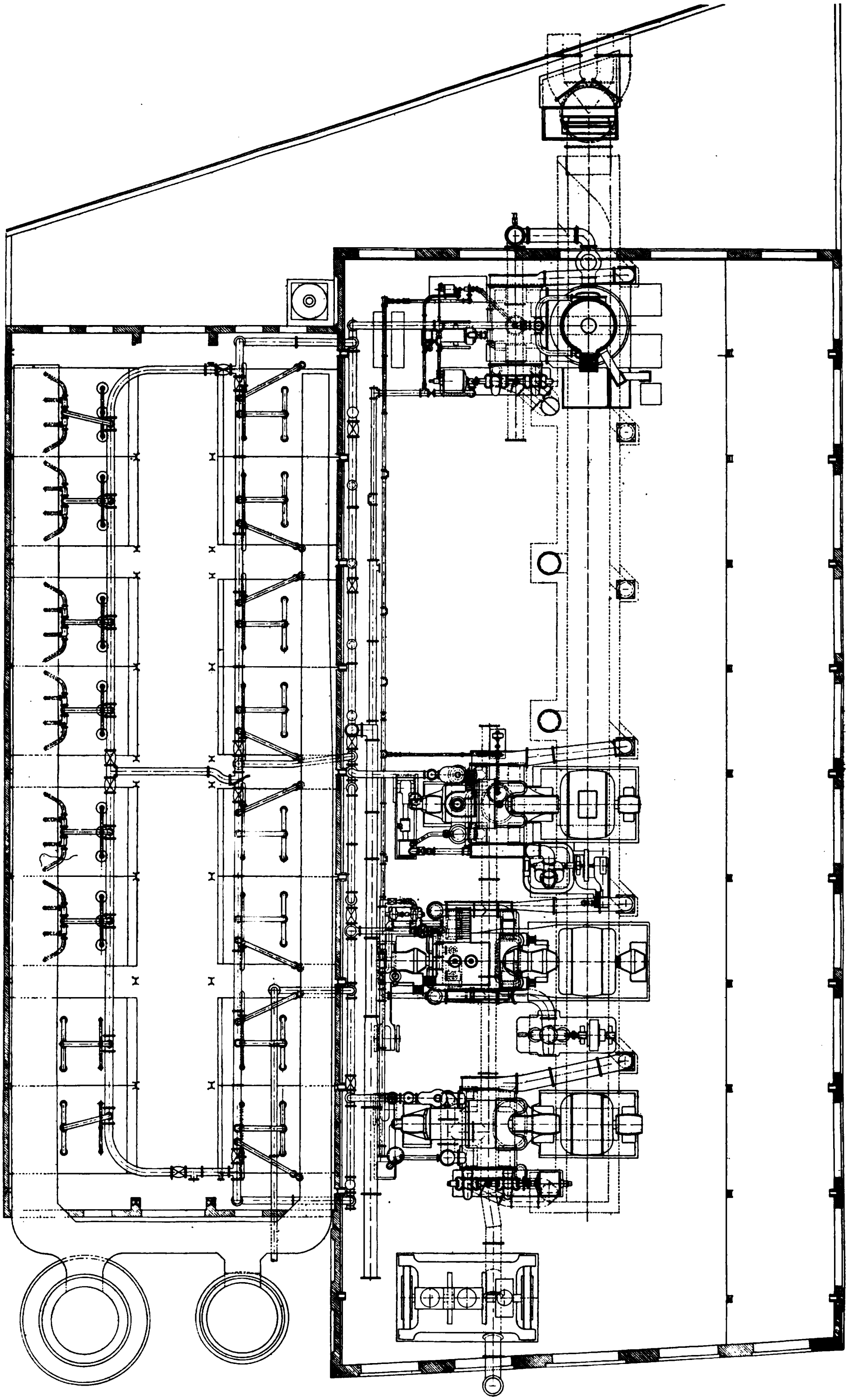


FIG. 130.—General Plan, Gold Street Station.

superheated steam bends from each boiler leading to the ring header are 8 in. in diameter.

The condensing tunnels are horseshoe in shape and of approximately 55 sq. ft. cross-section. They are of concrete construction.

The feed water mains are two lines of 6-in. pipe, one to each row of boilers. They are interconnected to provide for feeding any boiler from either line. The line to each boiler from these headers is 3-in. pipe.

The hot well returns are collected in an 8-in. header leading to the heater or in a 6-in. overflow line to the discharge tunnel. Two 6-in. connections to the city water mains furnish the make-up water. A fire system is also provided. There are two turbine-driven centrifugal four-stage feed pumps for regular service, and one reciprocating pump for emergencies and for boiler cleaning, fire service, etc. The latter is a part of the original installation and is never used under ordinary conditions. The centrifugal pumps deliver 1000 gal. per min. apiece against 225 lb. per sq. in. pressure. They run at 1675 rev. per min. An open heater is on the suction side of the feed pumps and takes steam from the auxiliary exhaust header with a connection through 8-in. pipe to the atmosphere stack. The hot-well returns and the make-up water enter the heater through 8-in. and 6-in. pipes respectively.

The four condensers are all of the surface type and contain 18,800, 25,000, 16,000 and 16,000 sq. ft. of surface, respectively. The first three are connected to the horizontal turbines. The third of these has an engine-driven 24-in. double-suction centrifugal circulating pump having a capacity of 18,000 gal. per min. The air pump is 12 by 26 by 18 in., running at 100 rev. per min. The hot-well outfits for all the condensers are similar, consisting, each, of a 5-in. centrifugal pump direct driven by a steam turbine.

The first condensing outfit is the same as that already described except that the circulator is a 30-in. centrifugal pump, handling 20,000 gal. per min. and motor-driven. The second condenser for the horizontal turbines also has a 30-in. centrifugal circulating pump, but with a capacity of 25,000 gal. per min. and

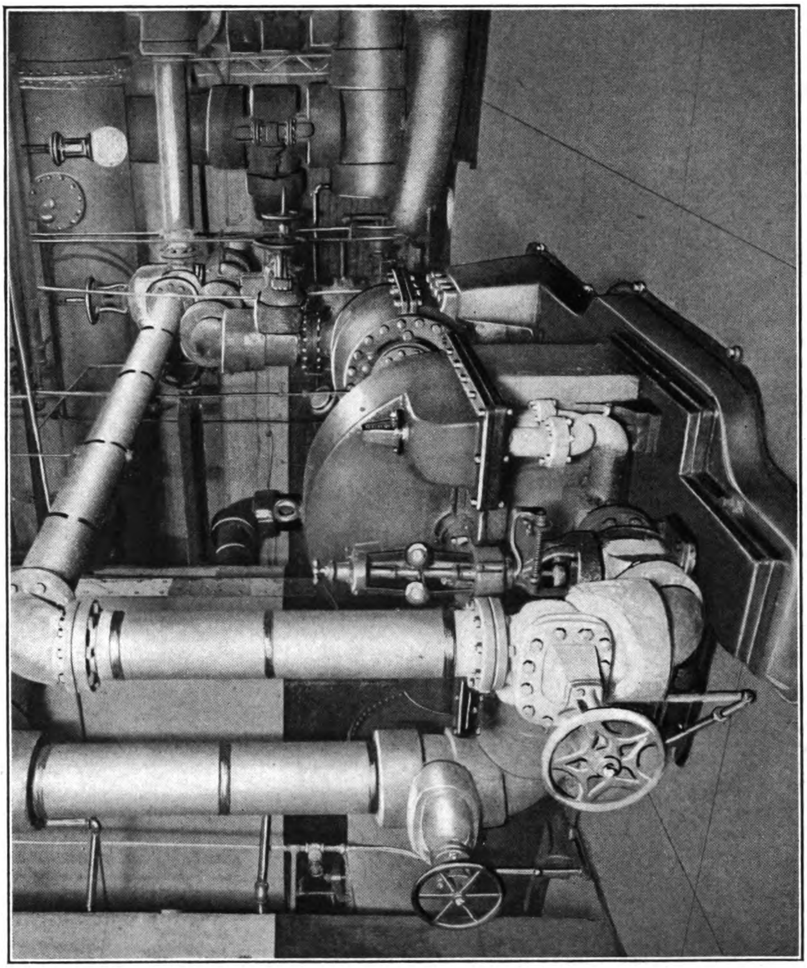


FIG. 131.—Pump Room, Gold Street Station.

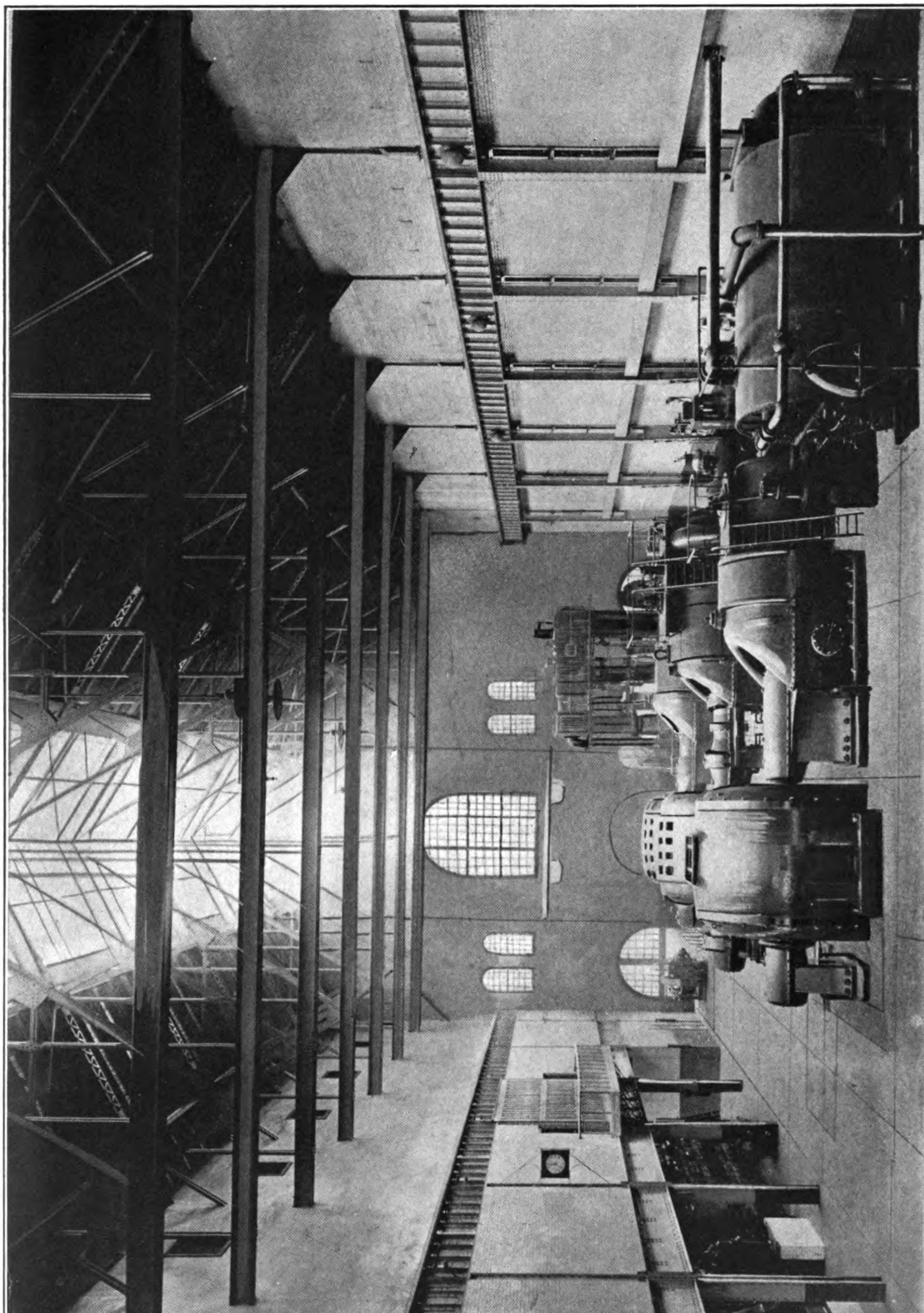


Fig. 132.—Operating Room, Gold Street Station.

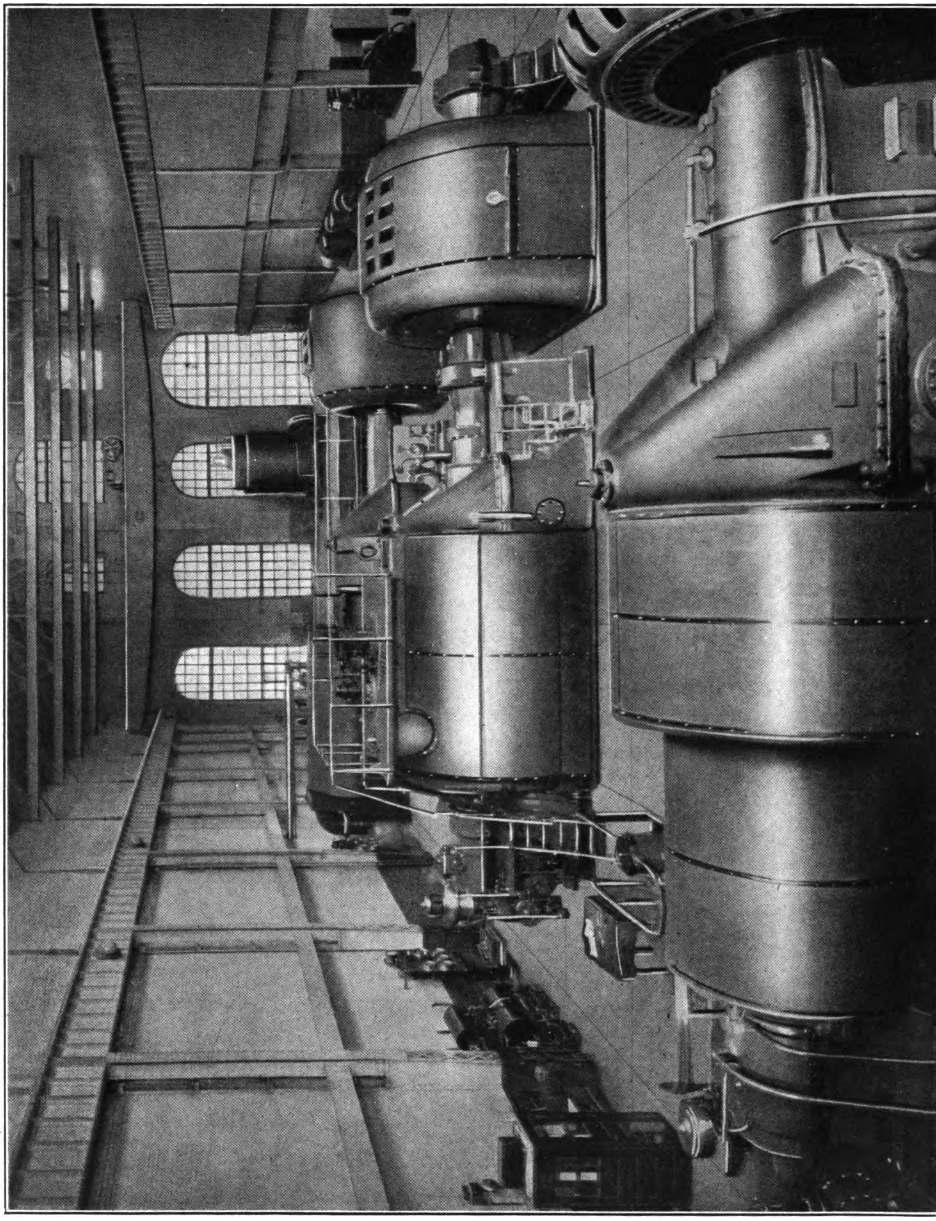


Fig. 133.—Operating Room, Gold Street Station.

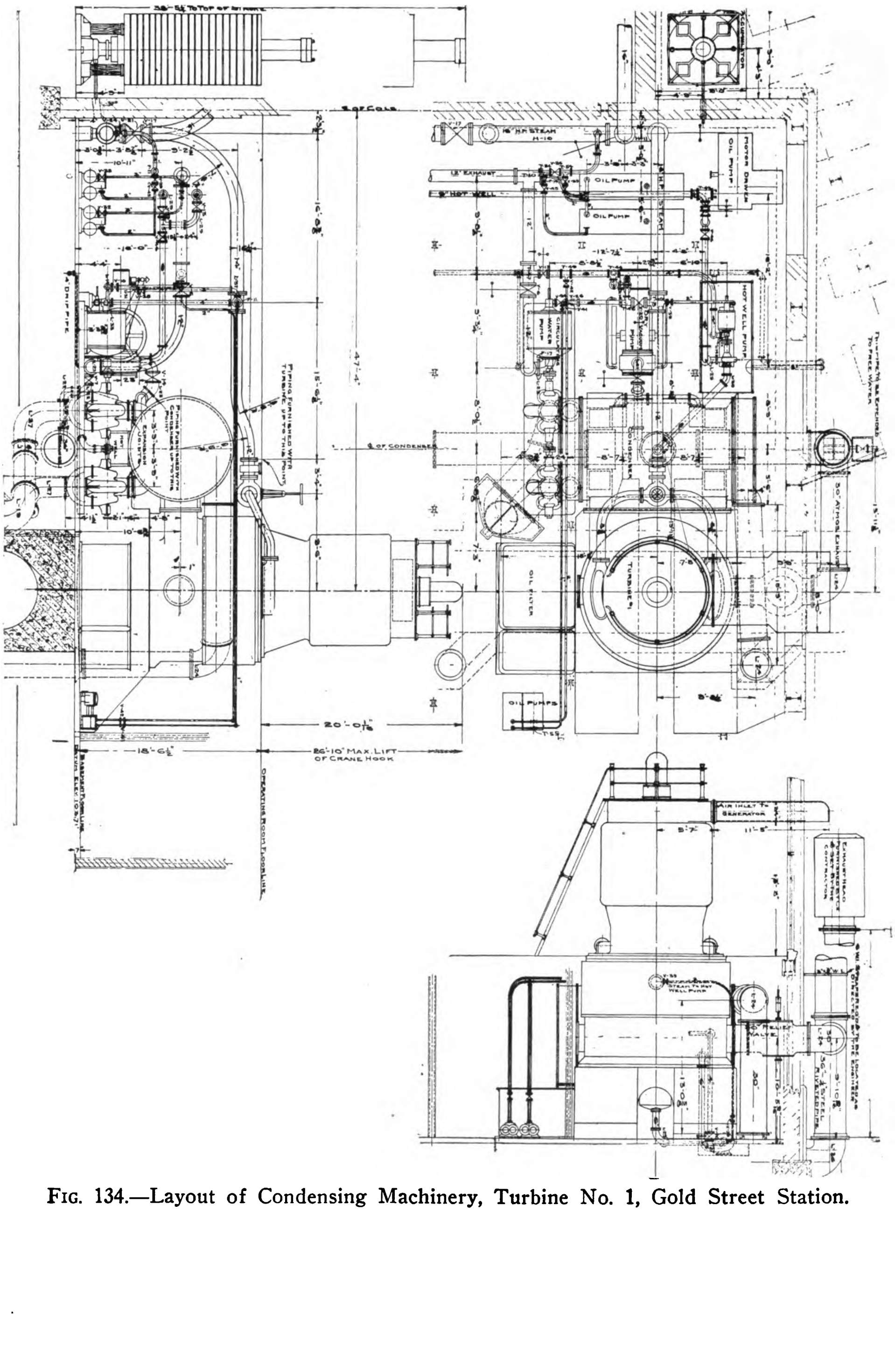


FIG. 134.—Layout of Condensing Machinery, Turbine No. 1, Gold Street Station.

double suctions. This machine also is driven by a motor. The air pump is double 12 by 24 in. and runs at 100 rev. per min.

The condenser for the vertical turbine contains 16,000 sq. ft. of surface and has two circulating pumps. These are 18-in. centrifugals running at 750 rev. per min. coupled to and driven by a 250-hp. steam turbine and have a combined capacity of 30,000 gal. per min. The dry vacuum pump is a 12 x 30 x 14-in. machine run at 100 rev. per min. This condenser has a turbine-driven centrifugal wet-vacuum pump similar to those on the other condensers.

The forced draft installation consists of six fans—three to a duct—set one at each end and one in the middle of the length of the duct. The four end fans are slow-speed radial blade type belted to steam turbines. The middle fans are of the multi-vane type and direct connected to steam turbines. The pressure maintained under the grates varies from 1 to 2½ in. of water.

Coal is handled by means of a twin two-man type coal tower set on the bulkhead, the coal being brought to the station by barges on the East River. The lift is 130 ft., and the buckets discharge into a hopper at the top of the tower. Thence the coal slides down through a crusher to cars operated by a cable railway over a bridge to the top of the boiler house. These cars discharge their contents into the coal bunkers, which are directly above the boilers, and the usual downtakes feed the latter. Most of the coal used is No. 3 buckwheat, as soft coal is used only during the peak load. The bunkers' capacity is 4500 tons.

The ashes are handled by ash cars on tracks in the boiler-house basement. They are pushed by hand to the river end of the building where they are hauled up a slight incline to the foot of the coal tower by a hoisting engine. A continuous over-lapping bucket conveyor carries the ashes up into an ash pocket built into the coal tower below the coal hopper, whence they are discharged into barges by means of chutes on the river side.

ELECTRICAL APPARATUS.

The exciters, a balancer set, the storage battery, a rotary converter and a 1000-amp. booster for charging, are all connected on a three-wire, d.-c. circuit, 125 volts on each side. To this circuit are connected the main generator fields, which take 125 volts for

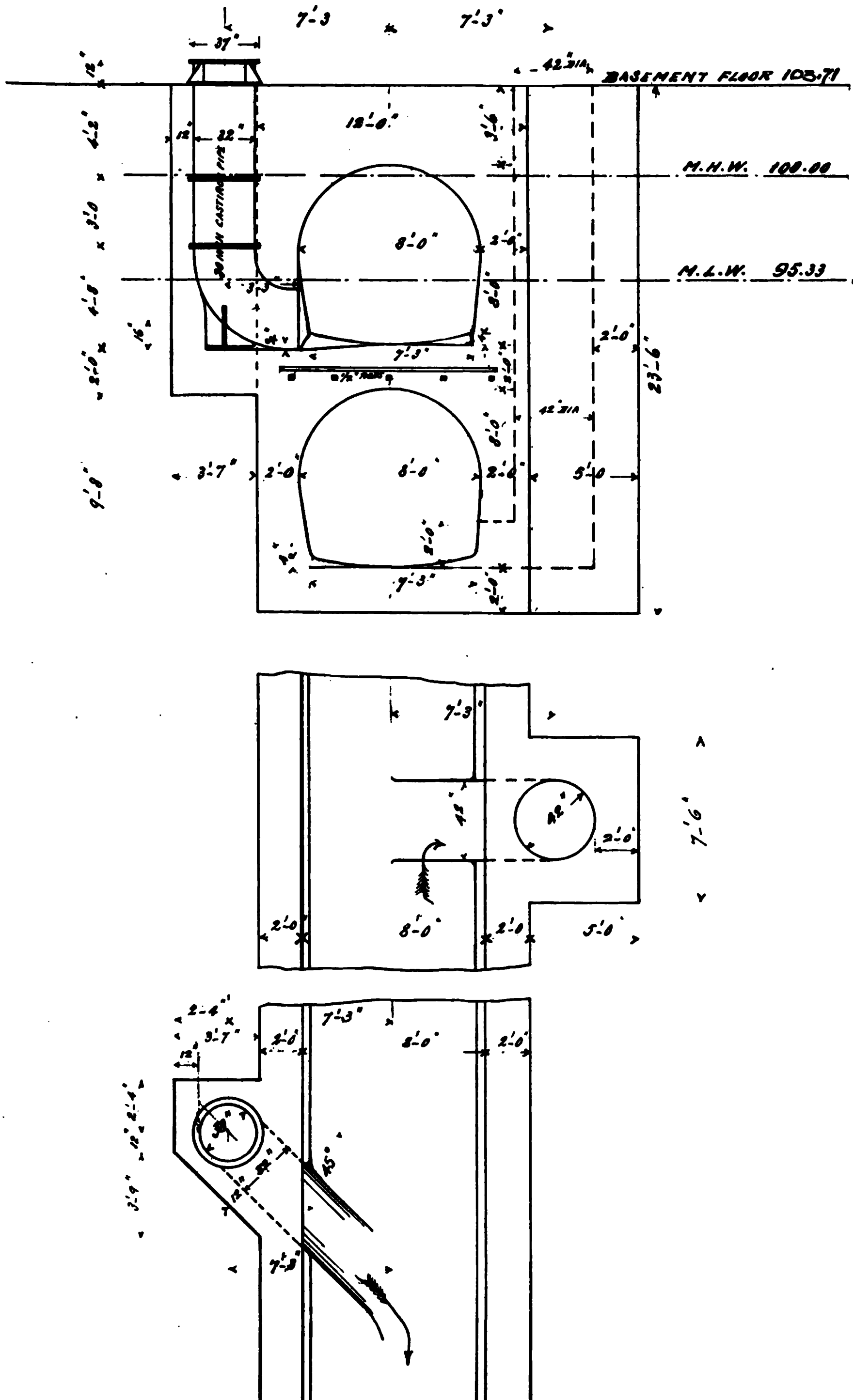


FIG. 135.—Sections of Condensing Tunnels, Gold Street Station.

excitation. There is an engine-driven exciter of 800 kw. This machine carries two 125-volt, d. c. generators, one on either side of the system. It stands at the south side of the operating room, next to the division wall. The rotary is a 1000-kw. machine, 250 volts, connected across the outside of the circuit. This machine can be cut off the excitation system and thrown over onto the low-tension outside feeders, of which there are three at present. In general, however, it is used on the excitation bus.

The storage battery, placed in the basement under the mezzanines, is of the R-39 type and consists of 150 cells, half on one side of the system and half on the other. A 45-kw. balancer completes the low-tension equipment. This set consists of two dynamos on the same shaft, each with its armature connected across one side of the d. c. system and its field across the other side. By this arrangement, if the load becomes unbalanced, the machine whose armature is connected across the lightly loaded side of the circuit, drives the other as a generator and thus evens up the distribution. When the loading is equal on the two sides, both machines run light. In putting in the main units, the practice is to even up the load on the exciter system by adding one machine alternately to first one side and then the other. If an even number of machines is in service, the load is practically balanced. With an odd number in, of course, the balancer is brought into play.

The low-tension switchboard is on the main engine-room floor on the Gold street side of the building, under the mezzanines. It has panels for the exciters, station power and lighting, the 1000-kw. rotary, storage battery, booster, low tension outside feeders and generator fields.

The high-tension a. c. system is of the remote-control type. The main control board is situated on the first mezzanine, on the eastern side of the operating room. This board controls the generator switches, the feeder switches and the feeder and generator selector switches, which are of the motor-operated type.

The generator and feeder switches are also situated on the first mezzanine. The feeder switches are automatic 300-amp. capacity. On the second mezzanine are located the feeder selector switches, motor operated, 500-amp. capacity, generator and generator selectors, 1200-amp. capacity, and the main and

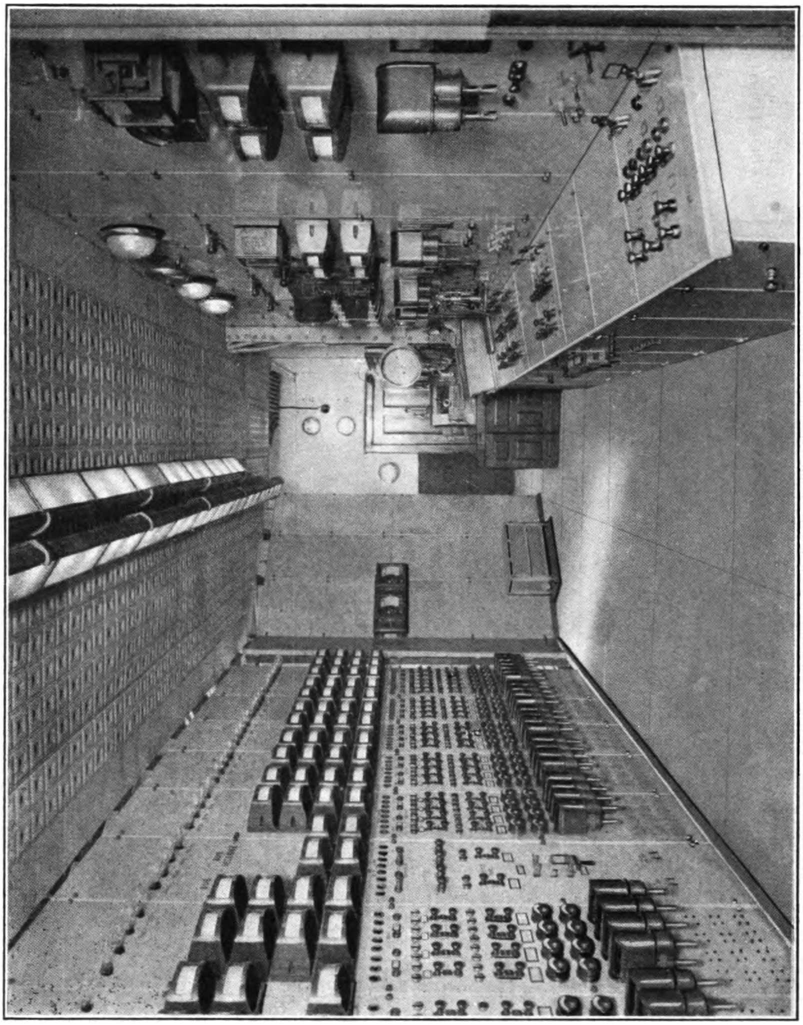


Fig. 136.—High-Tension Control Board, Gold Street Station.

Fig. 137.—Low-Tension Switchboard, Gold Street Station.

auxiliary bus-bars. Each bus is divided into three sections, and is planned to accommodate eight generators, three generators on each of two sections and two generators on the third section. The usual cross connections are provided to enable either bus to be used.

SUBSTATIONS

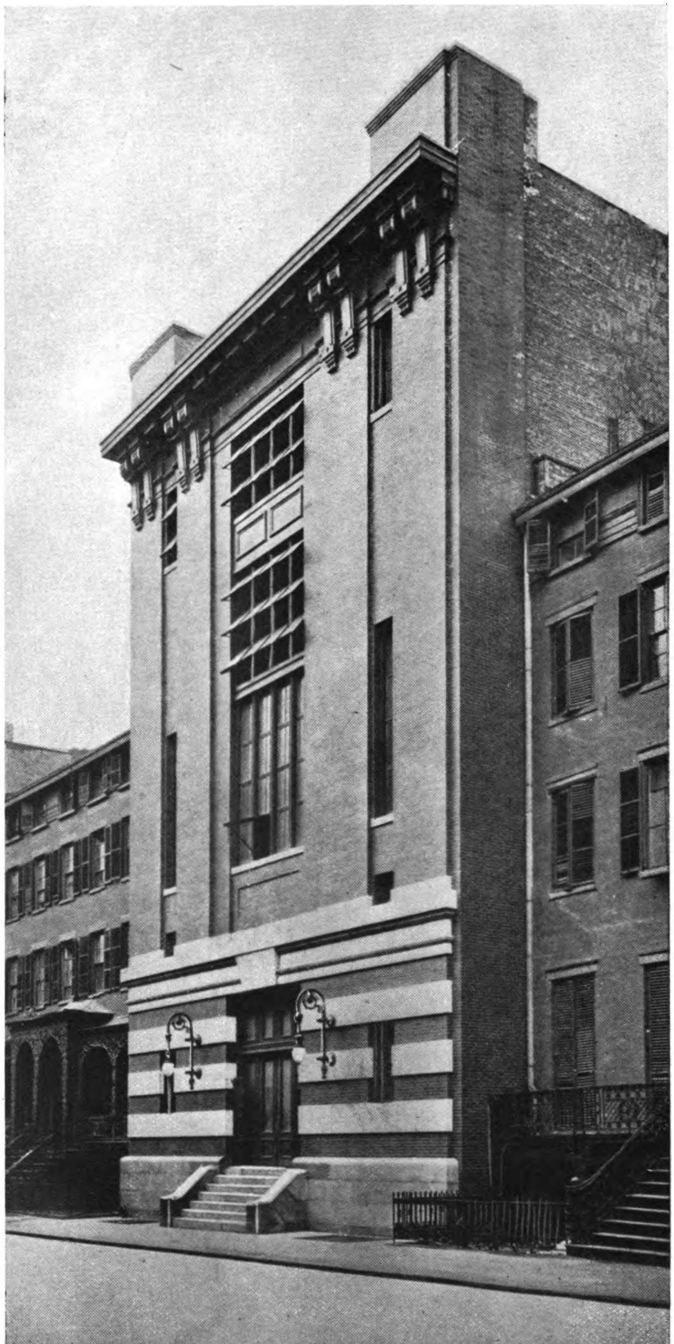


FIG. 138.—Sixteenth Street Substation.

SUBSTATIONS.

GENERAL TYPES.

The general arrangement of any substation varies somewhat, due to the capacity of the station and to the space available, and whether the current used is for railroad or light.

An example of a substation used for railroad purposes is the Tompkins Avenue substation of the Brooklyn Rapid Transit Company. The building is a steel frame structure, one story in height, with brick walls. The front and interior finish of buff brick.

The electrical equipment consists of five 1000-kw converters, each converter has mounted on one side an induction motor used in starting. Three 400-kw, single-phase, 6600-volt, air-blast transformers are used for each converter.

The high-tension switches are located in a switch house at the rear of the station, separated from the converter room by a brick wall. The feeder oil switches are solenoid operated, built in brick compartments with alberene barriers, from these switches the cables run to hand operated oil switches used for bus selection mounted on marble panels with alberene barriers. The main and auxiliary is carried on the rear of these barriers.

The usual type of standard railway machine and feeder panels are used for the direct-current switchboard.

Two examples of substations for light and power are the Sixty-fourth Street and the Sixteenth Street stations of the New York Edison Company.

In the Sixty-fourth Street station, the building is a reinforced concrete structure, with steel girders and concrete floor beams. The equipment of the station consists of five 2,000-kilowatt horizontal synchronous converters, with their transformers and switchboards on the first floor. In the basement are the compensator and boosters, and the blowers for the ventilation of the transformers. On the second floor is the battery and the high-tension switching compartments. Provision has been made, by the addition of another story, for the installation of an extra battery at some future date.

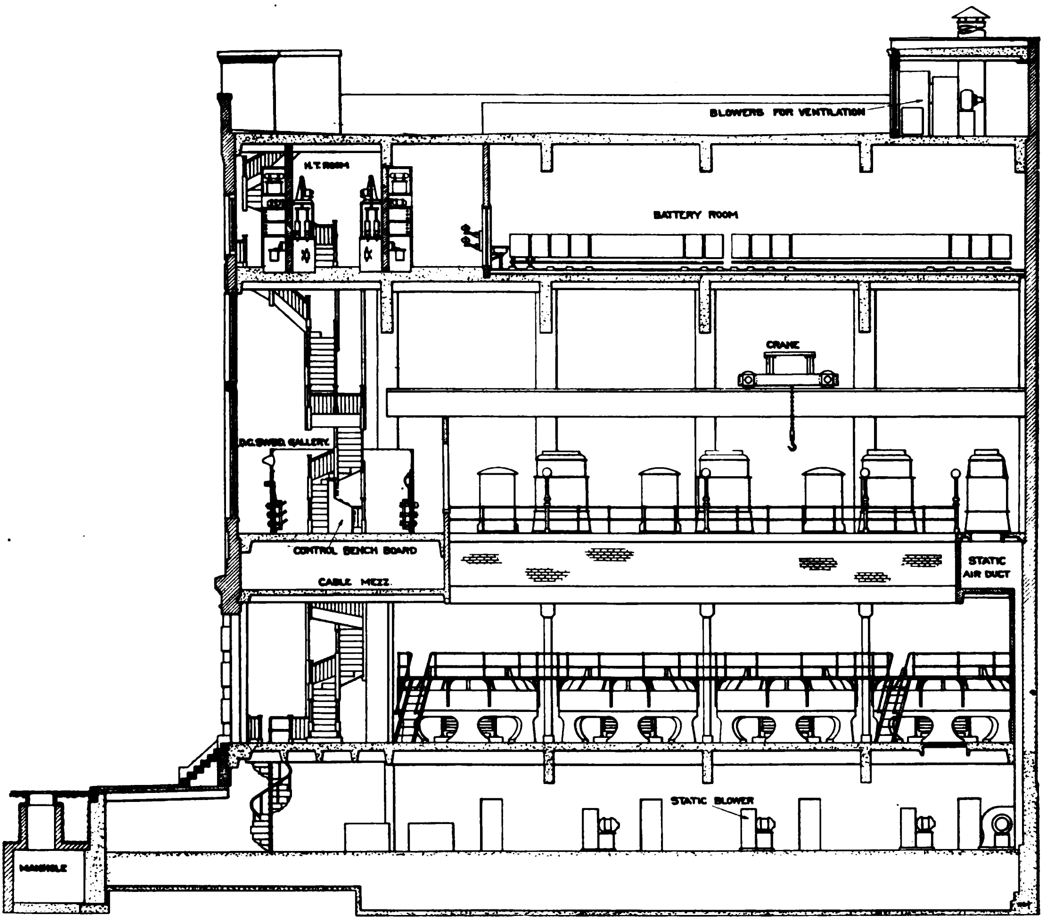


FIG. 139.—Longitudinal Section, Sixteenth Street Substation.

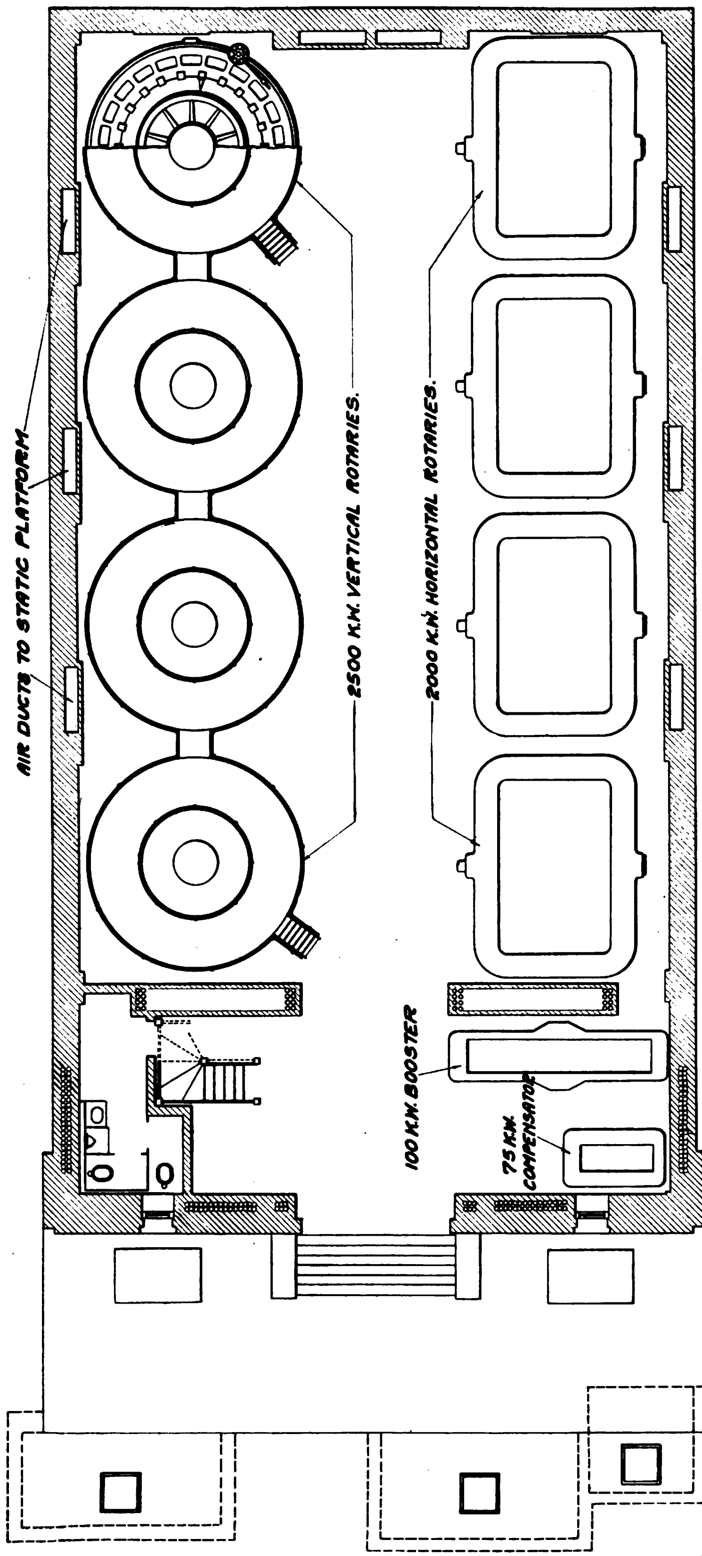


Fig. 140.—General Plan Sixteenth Street Substation.

The Sixteenth Street station has a capacity of 18,000 kilowatts; the horizontal and vertical types of converters are both used in this station. The general arrangement of this station is as follows: the converters on the first floor, with the transformers on a mezzanine, and the battery and high-tension switching compartments on the second floor. In the basement are located the blowers for the transformers and the oiling pumps for the vertical converters.

The building itself has a skeleton steel frame, the walls being of brick and non-supporting. The foundations are of concrete and the grillage of the steel columns rests on concrete piles carried to bed-rock. The foundations of the converters are isolated from the structure walls, and the building is further isolated by a 4-in. air space between it and the adjacent building, thus minimizing the transmission of vibration from the converters. The front of the building is of red brick, with a granite trim. The interior finish is of buff brick, all doors and windows having a copper kalamein trim.

The path of the circuit in the substations is as follows:

Coming into the station on the high-tension three conductor cable feeder as three-phase 6600-volt 25-cycle alternating current, the energy passes through the high-tension feeder compartments equipped with a 300-amp. type H three-pole motor-operated oil switch, and by means of two 300-amp. type K three-pole oil switches, is thrown on either the main or auxiliary high-tension buses. From these high-tension buses connections are again made by means of two K switches, and through an H switch to the transformers, thence through the three-phase induction regulator to the collector rings of the converter.

The direct-current terminals of the converter are wired to the positive and negative switches of the machine, which may be connected to three sets of busbars supplying energy to the low-tension direct-current feeders.

HIGH-TENSION COMPARTMENTS.

All of the high-tension switches are built in brick compartments, each compartment being complete in itself and protected from the next one by an 8-in. wall. Each set has one type H 300-amp. motor-operated oil switch used for disconnective or synchronizing purposes. In the rear of this compartment are

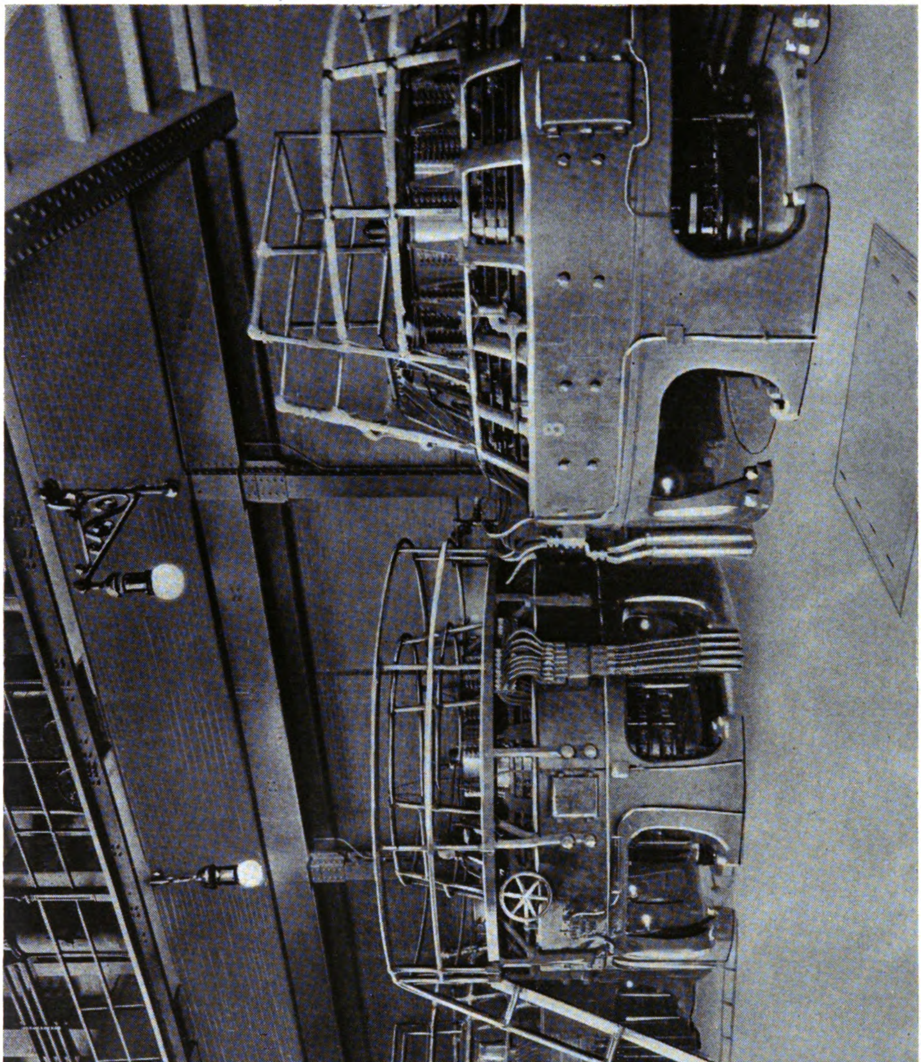


FIG. 141.—Operating Room, Sixteenth Street Substation.

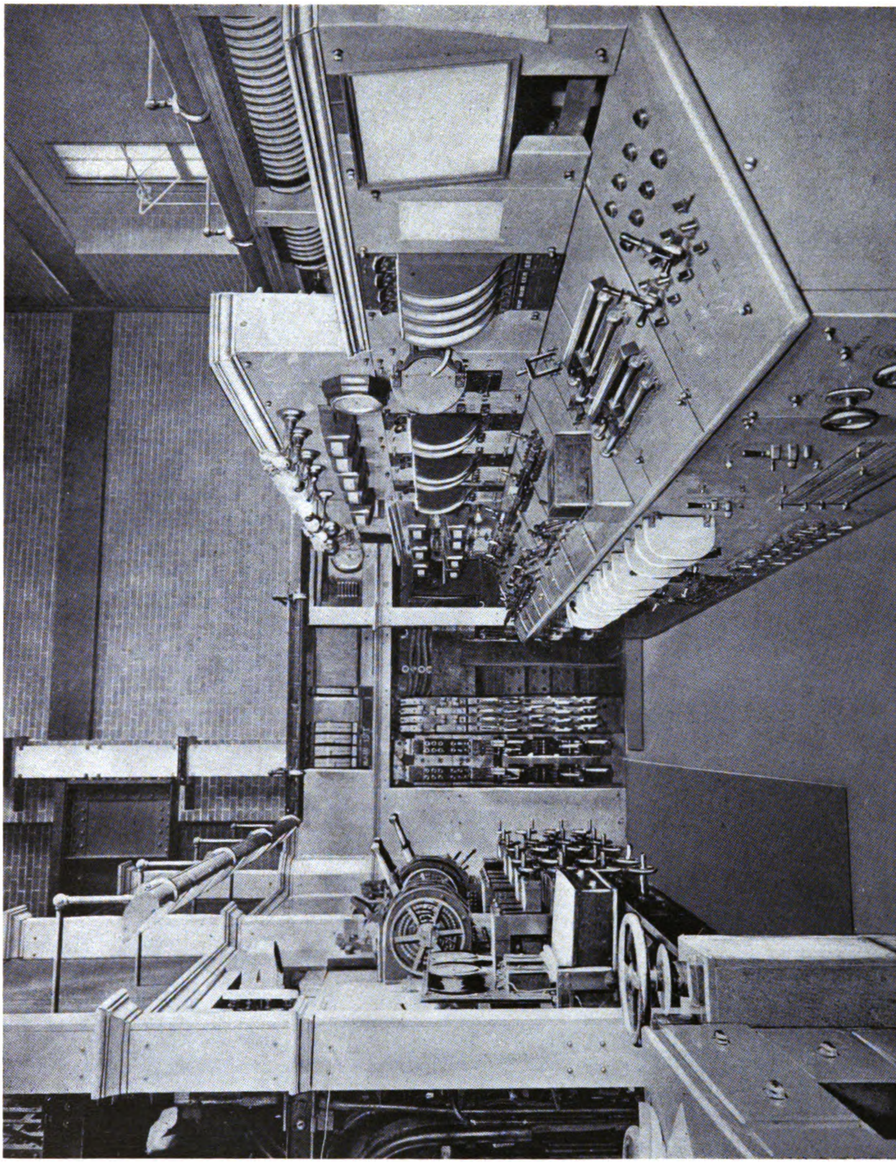


FIG. 142.—Control Bench Board, Sixteenth Street Substation.

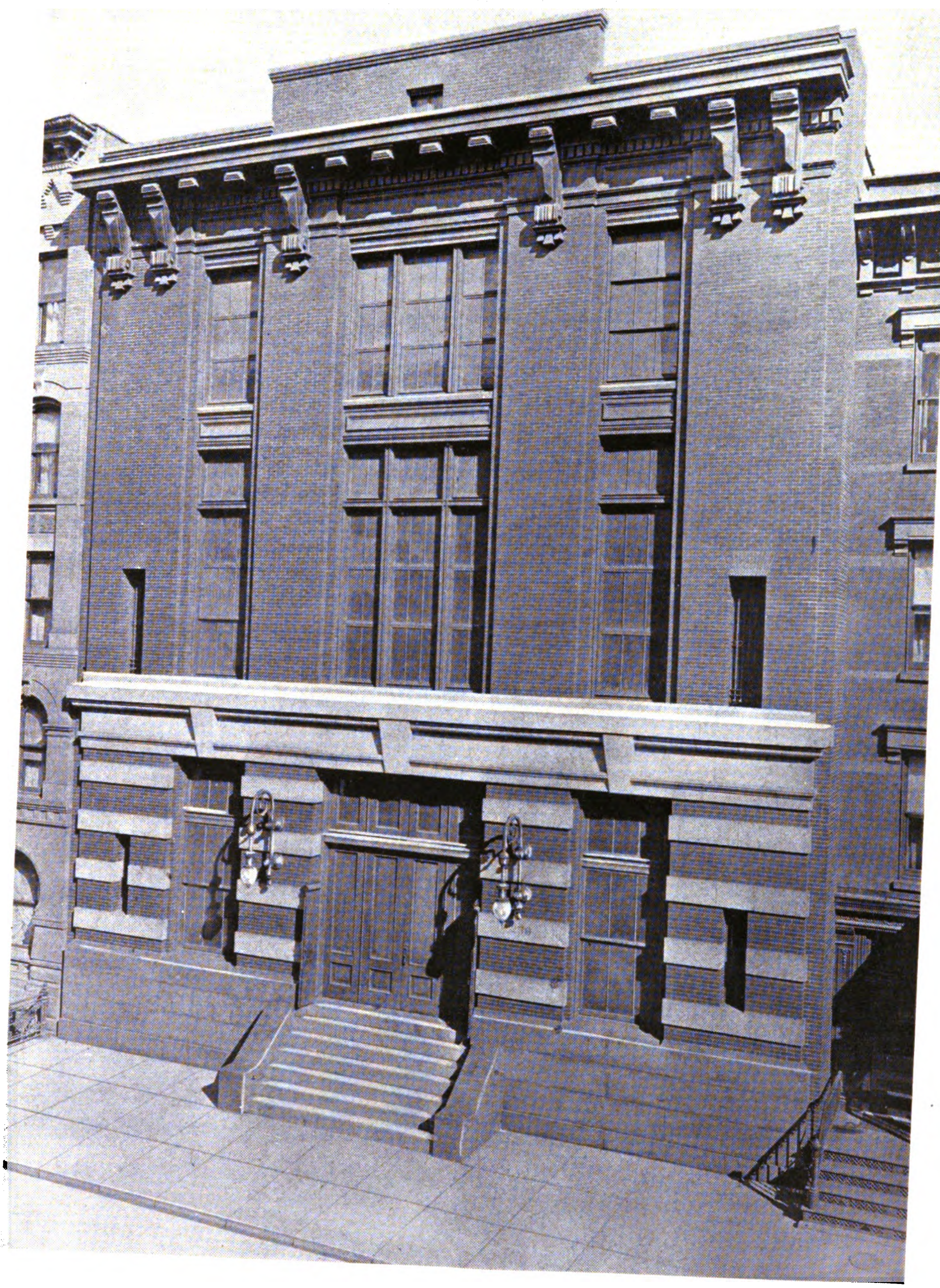


FIG. 143.—123d Street Substation.

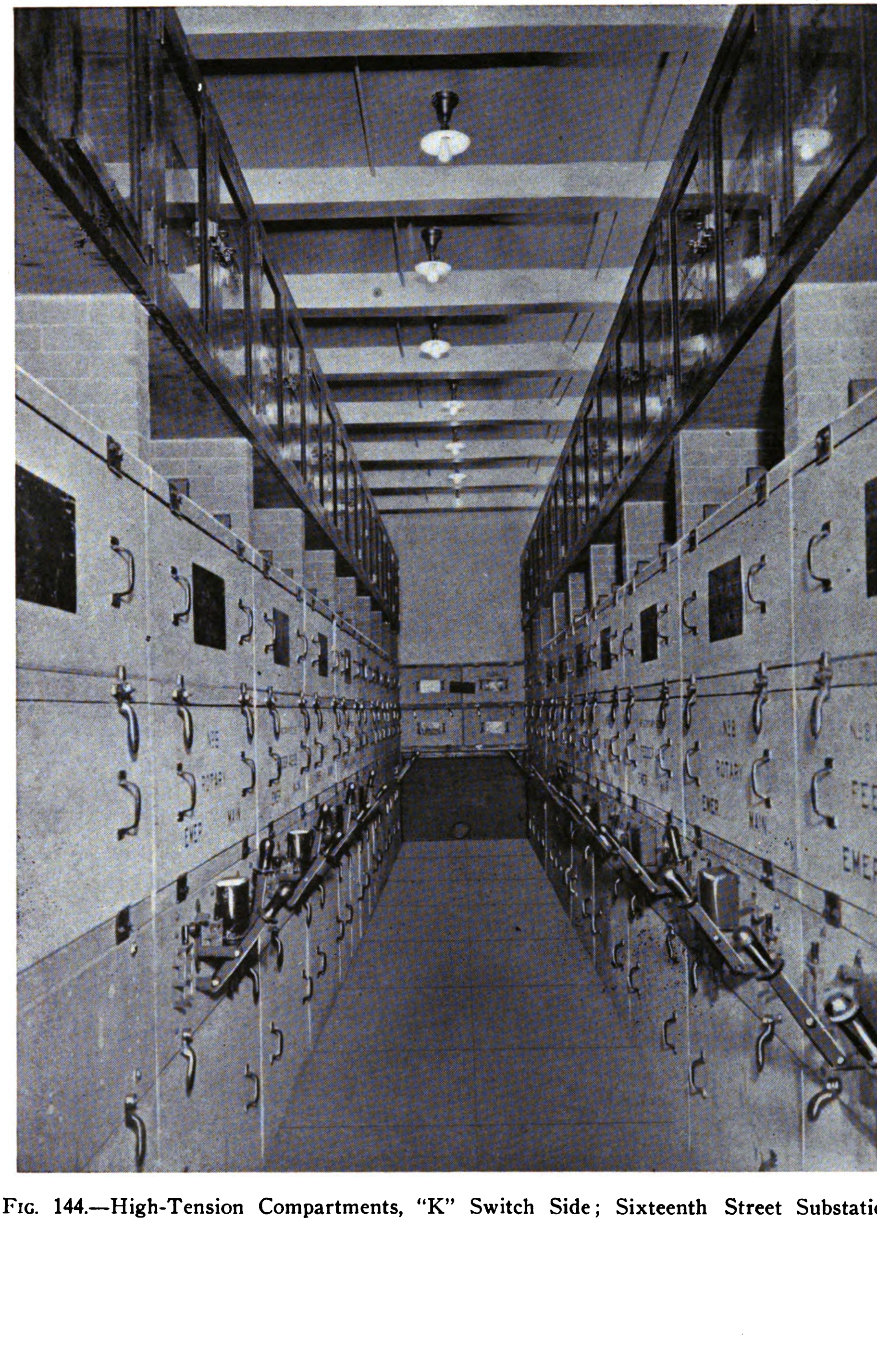


FIG. 144.—High-Tension Compartments, "K" Switch Side; Sixteenth Street Substation.

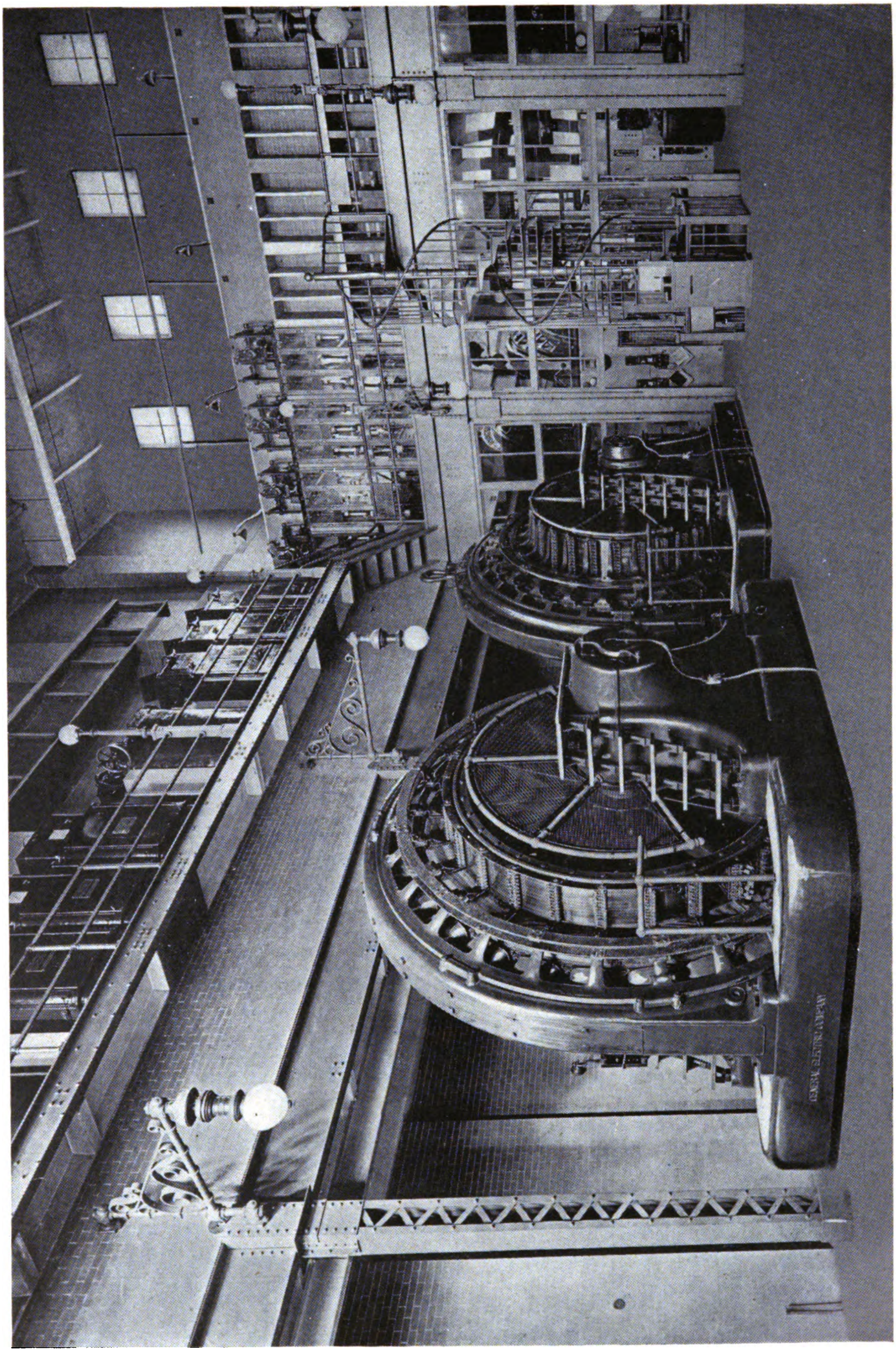


FIG. 145.—Operating Room, One Hundred and Twenty-third Street Substation.

mounted two type K 300-amp., solenoid-operated, oil switches that are used to select the bus on which the feeder or converter is to operate. Directly above are the two high-tension bus compartments, the solenoids for the "K" switches, and the potential transformers.

Both the front and rear of the compartments are protected by doors or covers of wired glass or concrete slabs. The arrangement of switches and buses in one of these compartments is shown in the illustration.

STATIC TRANSFORMERS.

The transformers are either of the polyphase or single-phase type, air-cooled; the single-phase type being used wherever space will permit. Each set has a separate blower, driven by an induction motor connected to the secondaries of its set, and the average pressure in the air duct is ¾ oz.

The primary and secondary transformers are wound for a ratio of transformation of 6300 to 170 volts, but other ratios may be obtained by connecting intermediate taps to compensate for drop on feeders of different lengths. They are wound with double secondary winding, connected in a double independent delta, the middle points of the delta being connected to the potential regulators.

POTENTIAL REGULATORS.

The induction regulators are connected in series between the transformers and the collector rings of the converter. Each regulator is of sufficient capacity to raise or lower the a. c. voltage 30 volts. These regulators are installed on the same platform with the transformers. The secondary connections between each transformer and the regulator are made by means of laminated copper bars with a cross section of 7 by ¾-in., insulated by means of alberene stone and supported by iron hangers. To avoid vibration, each transformer and regulator set is supported on a pneumatic device which is connected to the air compressor system of the stations. Connection is made between the regulator and the converter by means of cable run in duct.

SYNCHRONOUS CONVERTERS.

The converters are six-phase and of two sizes, the horizontal of 2000 kw. and the vertical of 2500 kw, the d. c. e.m.f. be-

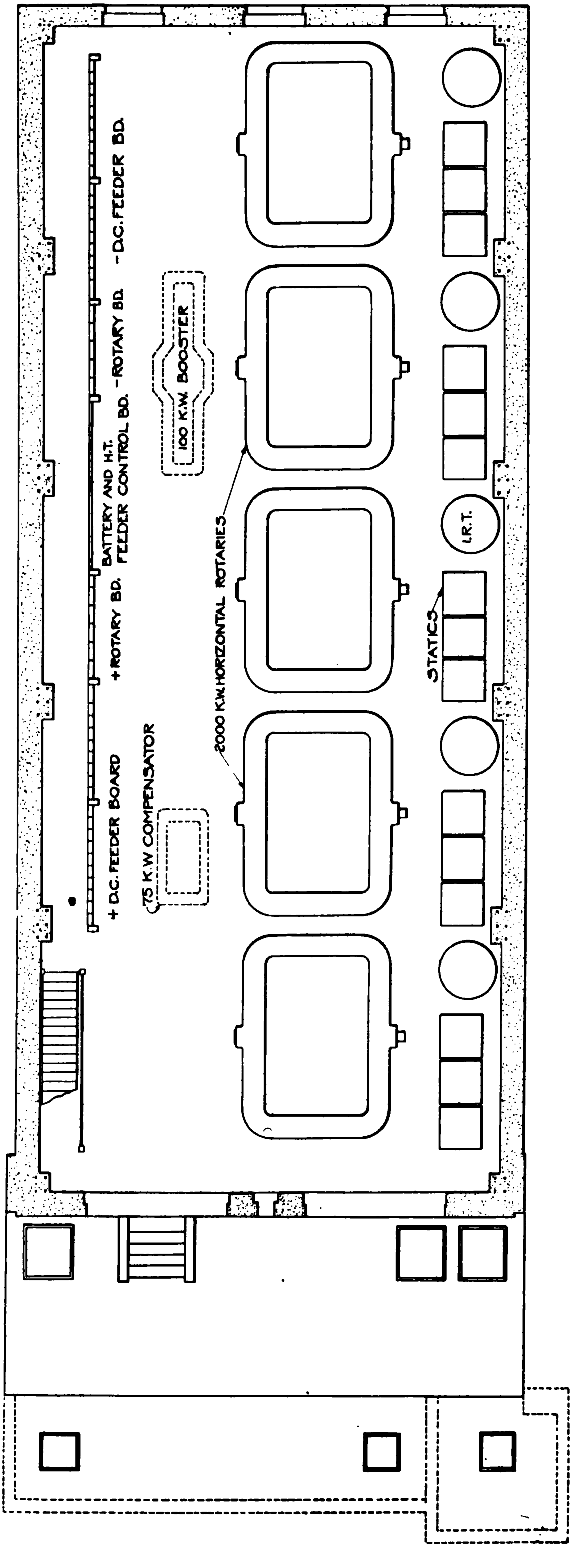


FIG. 146.—General Plan, Sixty-fourth Street Substation.

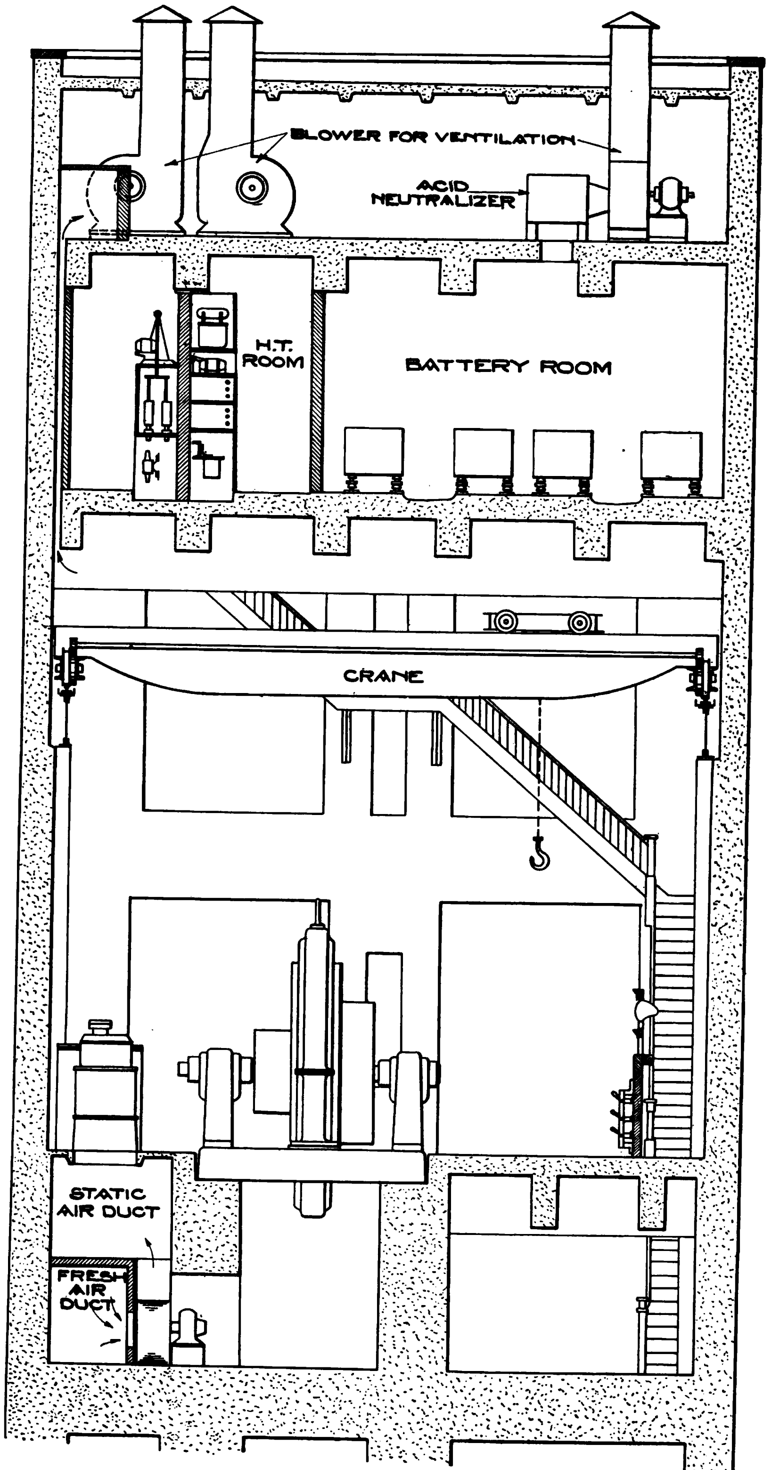


FIG. 147.—Cross Section, Sixty-fourth Street Substation.

ing 270 volts. The 2000 kw. horizontal converters have 26 poles and run at 115 rev. per min. The 2500 kw. have 22 poles, and run at 136 rev. per min. The vertical type has its armature mounted on a fixed shaft, the upper end of which has a roller bearing that is supplied with oil by means of a gravity oiling system. Each converter is provided with a speed limit device of the Shaefer-Budenberg type, which, when the machine reaches too high a speed, will trip the direct-current circuit breakers located on the switchboard. An automatic oscillating device is provided on the shaft of each horizontal type machine, in order to equalize the wear on the commutator and the collector rings.

THE LOW-TENSION D. C. SWITCHBOARD.

The direct-current switchboards of all the stations are divided into two independent sections for the positive and negative poles; the regulation and switching is usually done from the positive switchboard, which, in the 64th street station, is provided with a complete equipment of instruments. At the 16th street station, owing to the fact that two circuit breakers are used on each converter, the controlling and regulation is done from a bench board, including the controlling of the high-tension switches. The circuit breakers are mounted directly above the switches, so that when tripped by means of the speed-limit device on the converter, or by means of a control switch on the controlling panels, the converter is disconnected immediately at the bus.

The following instruments are used with each synchronous converter: One horizontal edgewise power-factor indicator; one vertical edgewise direct-current ammeter; one carbon-break field switch; two single-pole double-throw switches for operating the K switches; one single-pole double-throw switch for controlling the H switch used in synchronizing; one single double-throw switch for operating the circuit breakers; one double-pole, double-throw switch for controlling the potential regulator; one feed switch which controls the direct-current supply for the operation of these auxiliary devices, together with the necessary indicating lamps, in addition, each station is provided with an alternating-current voltmeter, a horizontal edgewise frequency indicator, and an alternating-current sliding contact switch which is connected to the synchronizing transformers of each set.

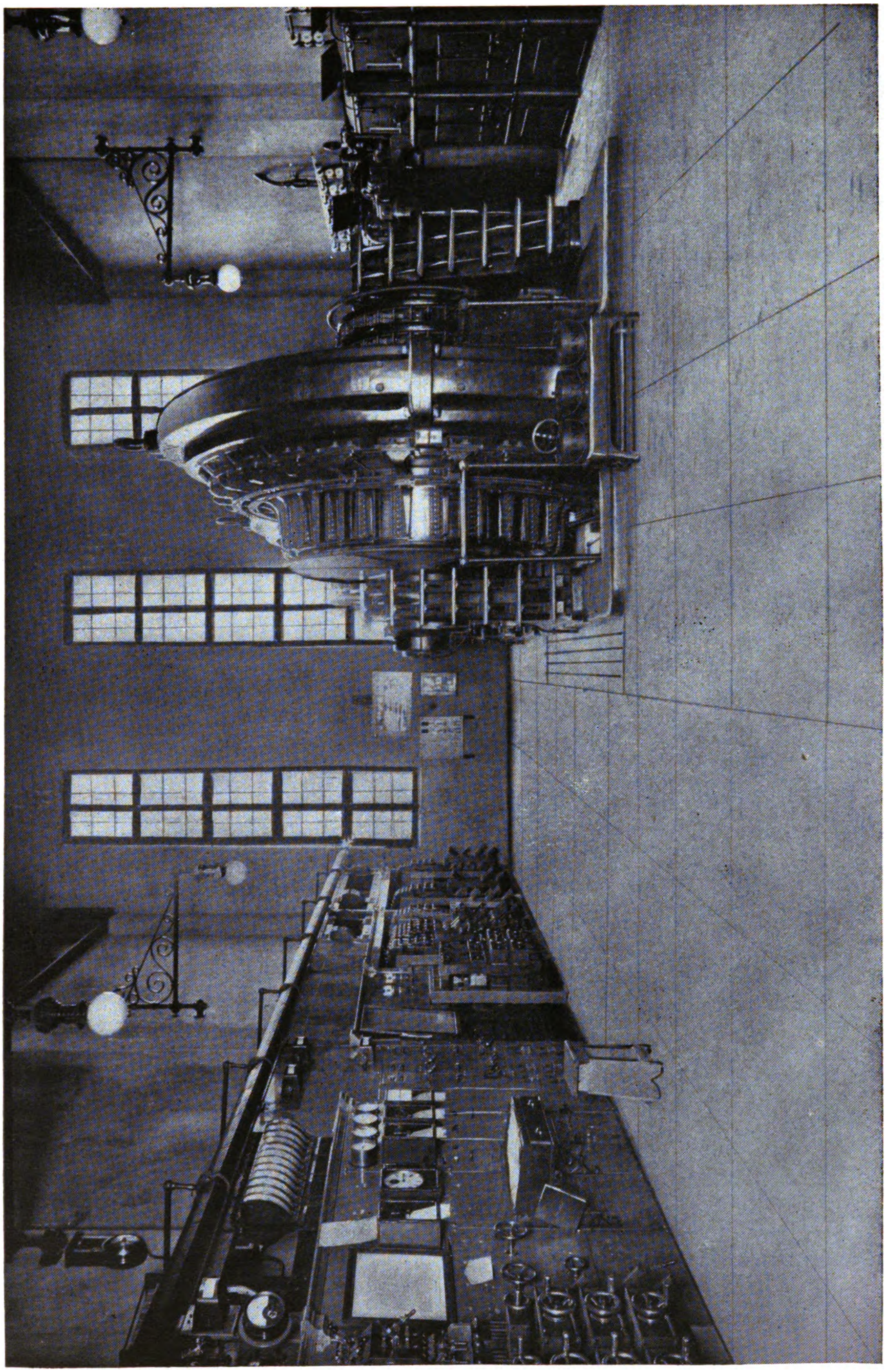


FIG. 148.—Operating Room, Sixty-fourth Street Substation.

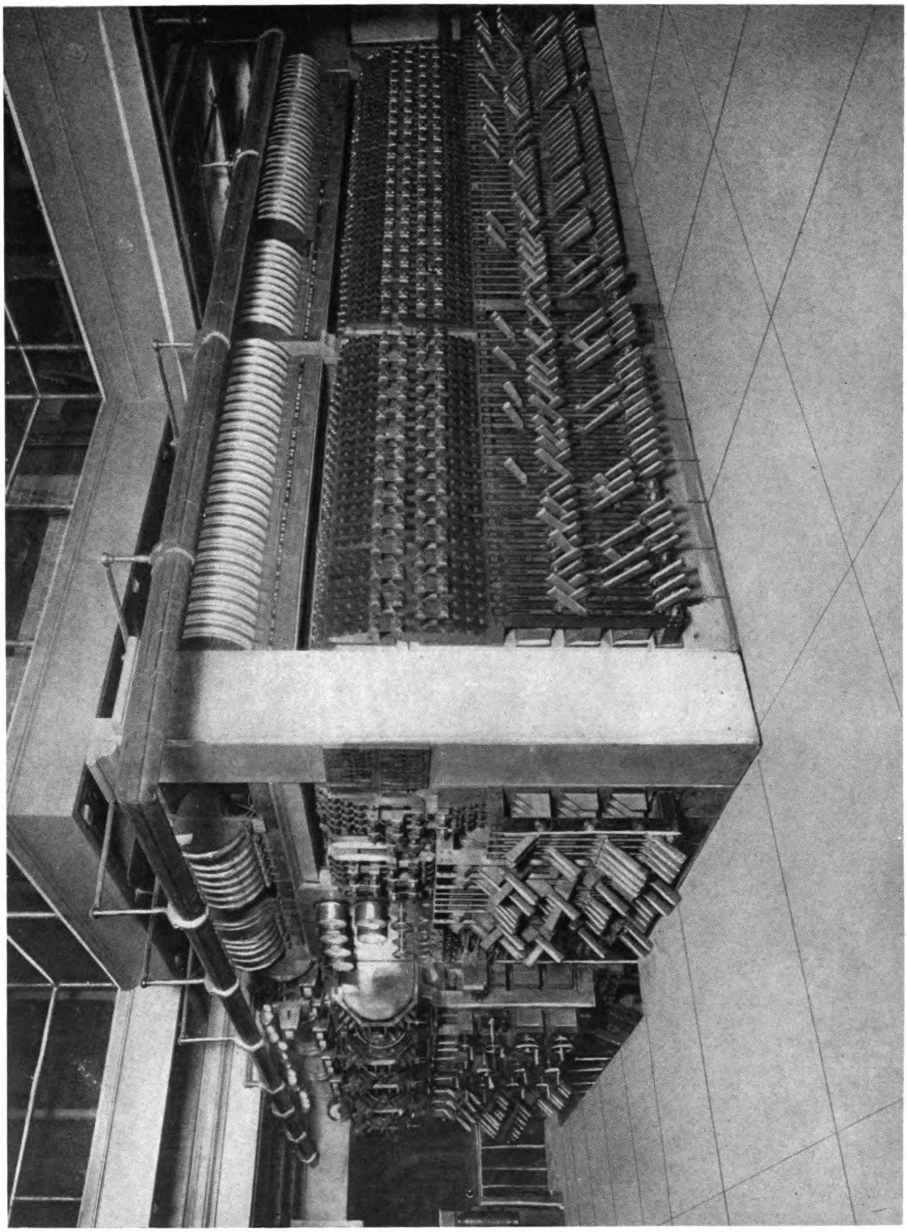


FIG. 149.—Synchronous Converter and Feeder Control Board, Twenty-Sixth Street Substation.

The low-tension feeder panels are grouped into a positive and negative board, each of which is provided with three sets of busbars mounted on the back of the panel and located at one side of each converter board. Each panel has four feeder switches, and above each feeder switch is mounted an edgewise ammeter. The feeder neutrals are not brought to the operating board, but are connected to the battery and compensator neutral bus located in the vault of the station.

All of the high-tension and low-tension cables are run in either pipe or vitrified duct; the cables in the pulling pits are also covered with split duct or split pipes. The ducts or pipes are all separated from each other and laid in cement, reducing the possibility of damage from a burn-out to a minimum.

Storage batteries are installed in all the stations from which direct current is distributed to insure continuity of the service.

The standard battery used contains 150 cells, 75 between the neutral and each outside wire. The latest type of battery which has been used at the 16th street station is the H exide 109, and has a capacity of 11,000 amperes at the one-hour rate, or 20,000 amperes for twenty minutes. Connections from the end cells of each battery are brought out to the positive and negative end cell switches, which are operated by a small motor controlled from the main switchboard. Each battery has two end-cell switches on each side, permitting, simultaneously, connections to two buses. The batteries are charged by a booster set, consisting of 150 hp. motor, 240 volts, and two generators each of 48 kw. and 30 volts, mounted on the same shaft.

The storage batteries in these stations being located upon the second floor, special precautions are necessary to prevent any acid which may leak from the tanks from damaging the structure. The latest type of battery floor construction consists, of first covering the entire floor with sheet lead, on top of this lead is laid about three inches of concrete, and on this concrete is laid a vitrified brick, each brick being spaced from the next by about 0.25 in., and these spaces afterwards filled with Hydrex compound, applied hot. The sheet lead is carried up on the side walls a distance of 14 in. high, and then turned or flashed into the wall. The ceilings and walls are covered with white plaster and for a distance of 6 feet above the floor are painted with the

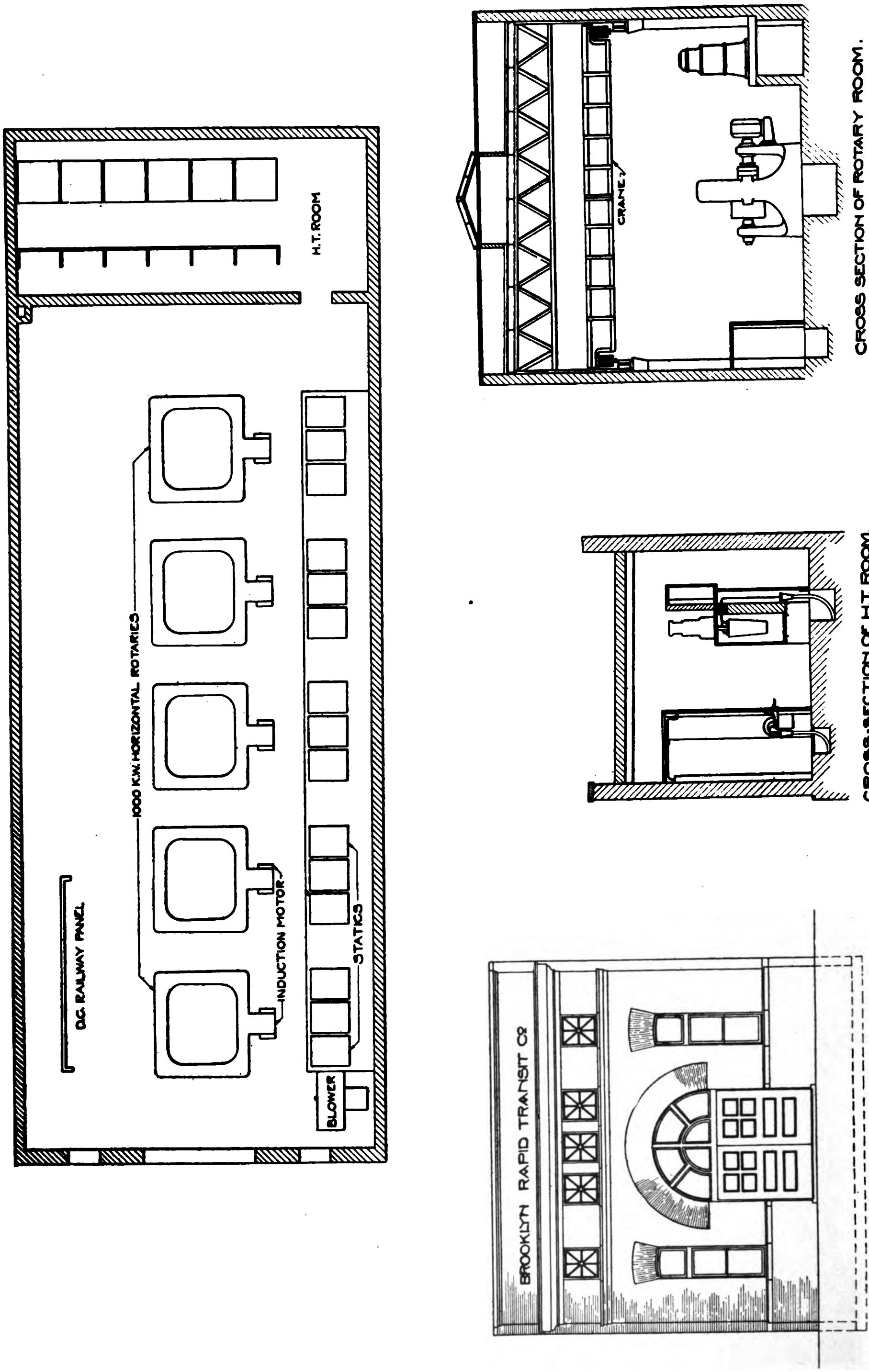


FIG. 150.—Tompkins Avenue Substation.

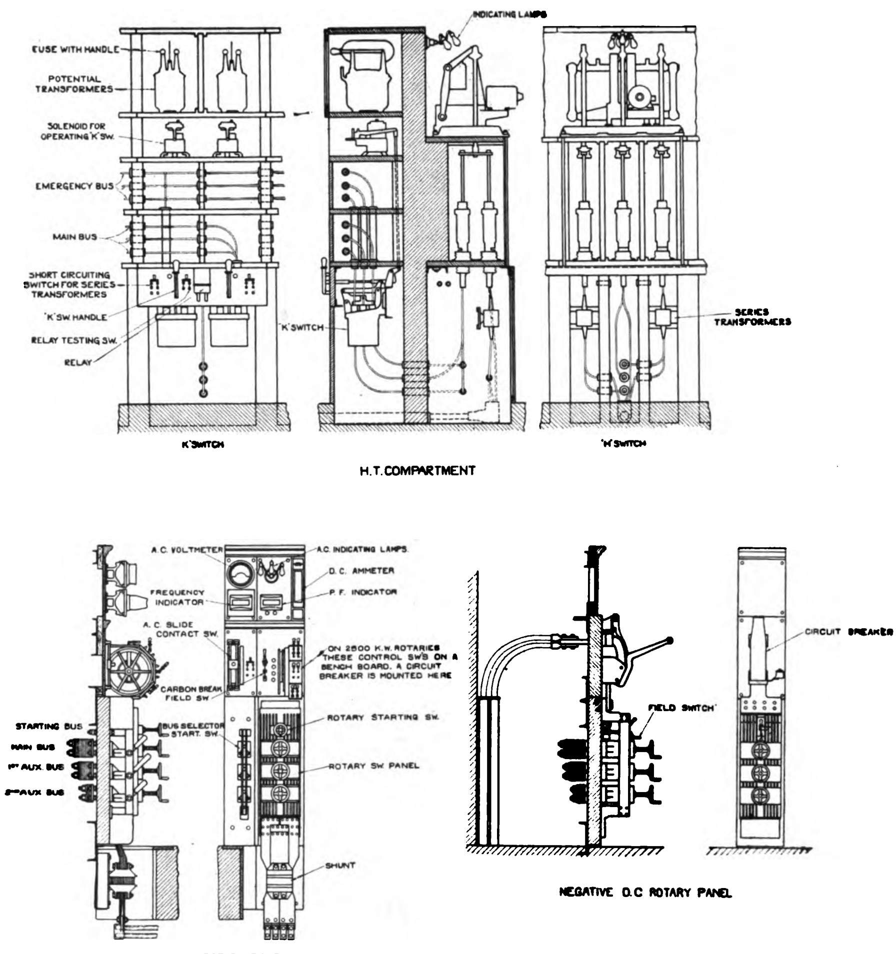


FIG. 151.—Details of High-Tension and Low-Tension Switch Gear.

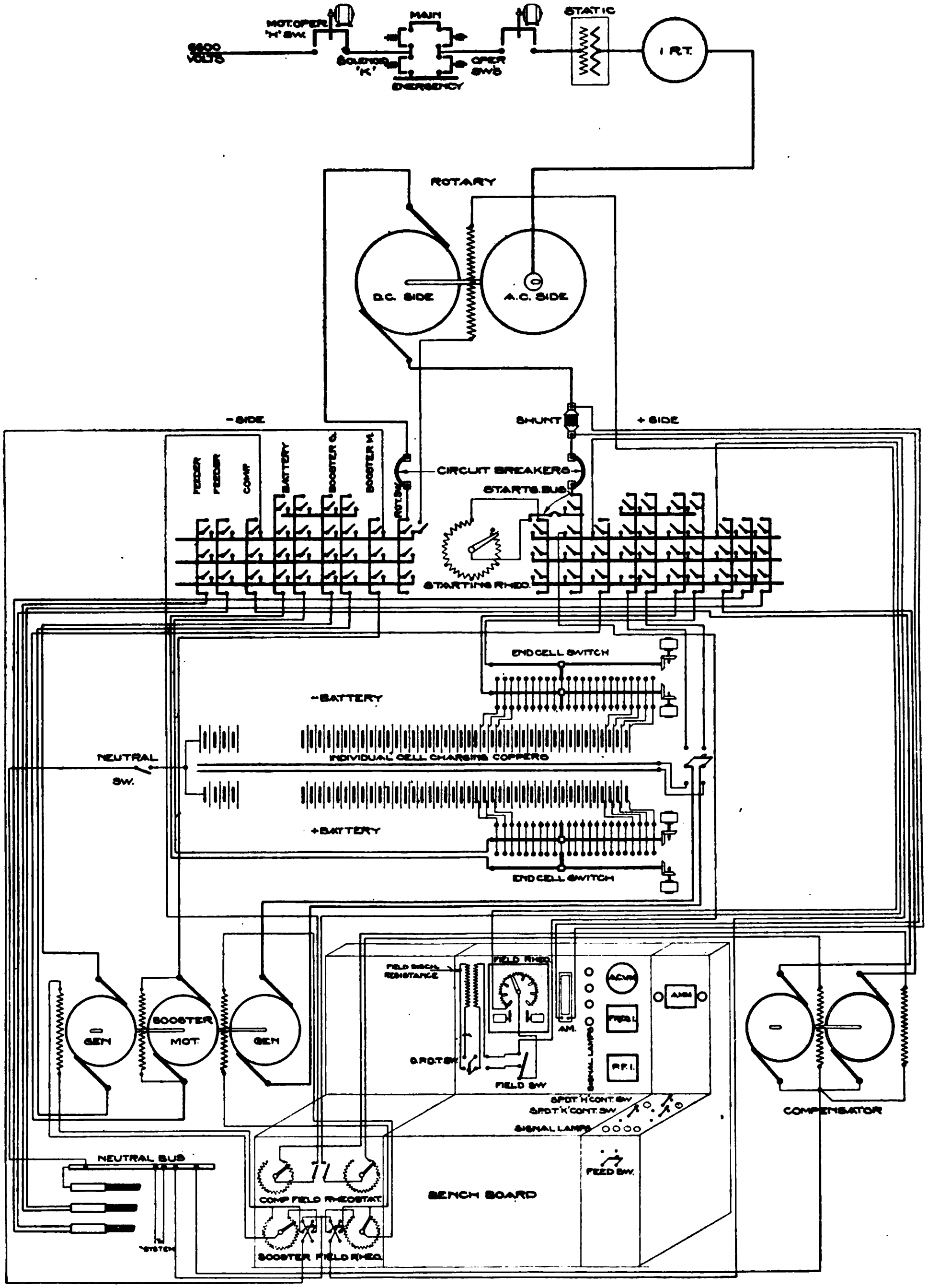


FIG. 152.—Diagram of Substation Connections.

Hydrex preservative paint. The floor is pitched, so that any water or acid on the floor will flow into the drain-box located at the end of the room. These drain boxes are of a special type and are all filled with lime, thus neutralizing the acid and preventing it from being carried into the sewer.

In addition to the battery which assists in maintaining the balance on the three-wire system, each substation is provided with a compensator or balancer set consisting of two 75-kw. 125-volt generators, mounted on the same shaft and connected in series across the system with the middle point connected to the neutral. When there is a perfect balance both machines run as motors, but in case the system is unbalanced one becomes a generator supplying the current to the weaker side.

VENTILATION.

The ventilation of these stations, necessitated by the heat thrown off by the machines, is taken care of, in the case of each station, by means of an exhaust flue leading up to the roof, where, by means of blowers, it is discharged into a stack. Air intakes are provided along the converter room at such a height as to prevent uncomfortable drafts.

Fresh air is forced into the battery rooms along the floor at the side walls, and is drawn out at the top at the far end, passing through a neutralizer, which consists of a series of perforated lead plates, which are washed down with water, and then into the exhaust fan, where it is discharged through a stack.

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